Quick Reference Guide

ABU	Accessory Business Unit
BA	British Airways
BEA	British European Airlines
BOAC	British Overseas Airways Corporation
CAA	Civil Aviation Authority
CFM56	GE & Snecma Engine Type
EBU	Engine Business Unit
EMMS	Engine Maintenance and Management Services
EROPS	Extended Range Operations
ESD	Engine Services Division
FAA	Federal Aviation Authority
GE	General Electric
GE90	GE Engine Type
G&H	RB211 Engine Type
IBU	Input Business Unit
JT8	Pratt and Whitney Engine
JT9	Pratt and Whitney Engine
OLYMPUS (OLY)	Concorde Engine
OWS	On Wing Support Unit
Pro-Model	Simulation Software
RB211	Rolls Royce Engine Type
RBU	Repair Business Unit
Refurbish	Engine Work Package
Repair	Engine Work Package
TAT	Turn Around Time
TCA	Teaching Company Associate
TCS	Teaching Company Scheme
Visual	Engine Work Package
WITNESS	Simulation Software

Abstract

The aim of this thesis was to investigate the ways of reducing the lead times of the strip to detail inspection of an aero engine overhaul facility. To achieve this, various methods were used. Initially dealing with the justification and construction of a simulation model followed by an examination of various scenarios to achieve the required reduction.

On completion of the scenarios, the detail view bay was targeted as the main area requiring change. A project was instigated to introduce teamworking to reduce the time it took to inspect an engine. This consolidation of the work was first of all tried on one type of engine module and then expanded. A measuring system was introduced to monitor the lead times of engines and modules passing through the input business unit. This involved the use of SPC charts to monitor lead times.

The results show a significant decrease in the time taken to work a RB211 module through the shops, coupled with an increase in throughput.

Declaration

This dissertation has not been nor is currently being submitted for the award of any other degree or similar qualification.

This dissertation is entirely the work of the author unless otherwise stated.

C.J.Holmes
Author

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Contents:

List of Tables

List of Figures

CHAPTER 1 INTRODUCTION

1.1 Engine Maintenance and Management Services (EMMS)

EMMS is part of General Electric (G.E.) Aircraft Engines Services Division, whose basic business is aero-engine overhaul and repair. EMMS currently employs one thousand people split into two sites, the major plant is based just outside Cardiff, at Nantgarw. The other, the On-Wing Support Unit is based at London's Heathrow airport.

All airlines are required to have their engines overhauled after a certain amount of time or flying hours / cycles. This is a law which all airlines must abide by or they can be fined or even shut down by the regulating bodies of the Civil Aviation Authority (CAA) or the Federal Aviation Authority (FAA).

1.2 The Business Scene

The global market for general aviation services, after a significant growth period in the late 1980's has been affected very badly by the recession in the early 1990's. As a result there is a global over capacity for aircraft services, including engine overhaul and repair. To retain existing customers and to gain new customers, various tasks have to be undertaken. Airlines measure the success of their engine overhauler and award contracts by three major categories:

1) Price
2) Performance (Engine reliability, fuel consumption levels, etc.)
3) Turn Around Times (TAT).

The purpose of this project is to reduce TAT's. The majority of airlines carry a surplus of engines so they have the ability to keep the fleet flying when engines are being overhauled. With the price of an aircraft engine being in the millions of pounds, this is an expensive stock to keep. The lower the TAT's, the lower the surplus of engines the airline needs to carry.

1.3 A Brief Company History

The company can trace its history back to 1924 and the days of Imperial Airways, when it was established to perform light maintenance tasks on the aircraft engines being operated at that time. Following the commencement of World War II in 1939, the decision was made to move the work from Croydon airport to Treforest, South Wales. This new facility commenced operations in 1940.

After the war British Overseas Airline Corporation (B.O.A.C.) was nationalised and in 1974 became part of British Airways (B.A.), following the merger of B.O.A.C. and British European Airlines (B.E.A.) The facility gradually moved from Treforest to its present site at Nantgarw, where the original testbeds had existed. In 1990 the company celebrated 50 years of continuous operation of the Nantgarw facility.

1.3.1 Recent History

Approximately 18 months before the sale of the plant to G.E. Engine Services Division (E.S.D.), B.A. announced its new policy and established the engine overhaul business as a separate cost centre away from the large B.A. Engineering Department. This effectively meant that British Airways Engine Overhaul Limited (B.E.O.L.) became a separate business, but was owned by B.A. The declared reason for this being the desire of B.A. to establish true costing of the work being undertaken and to establish the true cost of ownership of the engines being operated.

It was at this time that B.A. was conducting a review of all its activities. This resulted in the core activity being identified as the provision of aircraft seats to the general public. Other operations such as engine overhaul, catering and maintenance of ground support equipment could be supported by a third party (contracted out).

The result of this was that B.E.O.L. was sold to G.E. for £288 million pounds, the sale being ratified on December 2nd 1991. This sale was not without problems. The international press made great play of an alleged tie up between the sale of the company and the purchase by B.A. of the new, and as yet untried *GE90* engine to power its new fleet of Boeing 777 aircraft. G.E. was at this time desperate to find a launch customer of international standing.

1.3.2 G.E. Strengthens its Position

The G.E. view of the sale was that it had improved the companies position on two counts. Firstly, it had enabled the company to gain a foothold in the European and Middle Eastern markets for engine overhauls, and the purchase firmly complemented its existing engine overhaul business. There are two G.E. owned engine overhaul agencies already in existence in the mainland US. Secondly, G.E. was now in a very strong marketing position (Moorefield 1994), having the unique ability to overhaul the engines of the three major engine manufactures. These being Rolls Royce, Pratt and Whitney and General Electric. G.E. could now overhaul the engines of its competitors. This puts G.E. in a very strong marketing position, being able to offer airlines a complete overhaul package for all their engines.

1.3.3 History Affecting this Project

Due to the world-wide recession, and events such as the Gulf war, customers attitudes were changing. All the airlines had higher expectations. Their profit margins were in serious decline, and they began to pass this on to their suppliers, with demands for decreased cost and turn around time. They also required increased quality in the products they were being supplied with. As a result a complete restructuring of the business took place. This has resulted in a flatter management structure, a removal of the beauracracy and of major influence on the morale of the facility, a downsizing exercise. This reduced the number of people employed by 220, one-sixth of the entire workforce. This was done on August 26th 1993, and its affect on TAT will be discussed later.

Duncanson (1993) in an interview with Aircraft Maintenance International sees the way forward for EMMS as having two key elements. These being 'the ability to improve our product and managing the costs within the business. We are delayering the organisation, removing various levels of management, because it slows down the decision- making process and stops us reaching our full potential.'

1.4 The Teaching Company Scheme

The Teaching Company Scheme (TCS) is a government backed scheme and has, in the words of the Teaching Company Directorate, *'helped to link hundreds of companies of all sizes with academic teams in institutes of higher education all over the UK. In operation each company is partnered by a nearby university or polytechnic group with relevant specialist expertise.*

Each partnership is called a Teaching Company Programme. It works in one or more project areas as defined by the company as essential to improving its effectiveness and central to its future, but beyond its existing resources.

Academics participate in the Programme by being involved with company managers in the joint supervision and direction of the work of a group of high quality young graduates.

The graduates become Teaching Company Associates (Associate). They are appointed by the academic department concerned and are paid full industrial salaries to work for two years on the specified projects.'

Teaching Company Scheme. Putting ideas to work. Teaching Company Directorate, Hillside House, 79 London Street, Faringdon, Oxon.

1.4.1 The Authors Role in the Project

The author produced this thesis whilst working for EMMS as part of a two year Teaching Company project in conjunction with the University of Glamorgan. The work was carried out over a period from June 15th 1992 to 1st June 1994. The author then went on to work for EMMS, which later became GE Aircraft Engines Wales, as project leader introducing the *GE90* Engine into the facility.

1.5 The Project

The original project conception was to have three associates supporting each of the major business units - input, repair and engines (build). The objective being to reduce TAT in each of the areas. Only two associates were employed, supporting the input and repair business units. This project will deal with TAT reductions in the Input Business Unit.

CHAPTER 2 INVESTIGATION OF THE PROBLEM

2.1 Engine Types

EMMS deals with a large variety of Engine Types these are shown in Table 1:

Table 1- Engines Overhauled at the EMMS Facility

ENGINE	MANUFACTURER	AIRCRAFT
OLYMPUS	ROLLS ROYCE	Concorde
RB211 - 22B	ROLLS ROYCE	Boeing 747 / 767, Lockheed L1011
RB211 - 535	ROLLS ROYCE	Boeing 757-200
RB211 - D4	ROLLS ROYCE	Boeing 747-200
RB211 - BO2	ROLLS ROYCE	Gulf Airlines - Tristar
RB211 - G+H	ROLLS ROYCE	Boeing 747-400, 767-300
JT9	PRATT & WHITNEY	Boeing 747-100
JT8	PRATT & WHITNEY	Boeing 737
CFM56 - 3 / 5	CFMI / GE	Boeing 737, Airbus A320
GE90	GE / CFMI / FIAT / IHI	Boeing 777

It is this large variety of engine types that causes some of the major problems in scheduling work through the base. EMMS is the only overhaul base in the world that has the capability to deal with Rolls Royce, Pratt and Whitney and General Electric engines.

2.1.1 The Jet Engine

The Gas Turbine Engine, commonly referred to as the jet engine is an internal combustion engine which produces power by the controlled burning of fuel. In the gas turbine, air is compressed, mixed with the fuel and the mixture ignited and burnt. The heat produced causes a rapid expansion of the gas which is used to do the work. The continuously heated airflow is forced out of the engine through a nozzle at the rear. The ratio of secondary to primary airflow is called the bypass ratio. The Pratt and Whitney JT9D, CFM56, and Rolls Royce RB211 engines are all high by-pass jet engines. This means that 75% of the thrust comes from the fan at the front of the engine. The JT8 engine is a low by-pass jet engine. Finally, there is the Rolls Royce Olympus which is a turbo jet engine. This engine has no fan or propeller and operates most efficiently at high altitude and speed.

The engines are all constructed from a series of modules such as the compressor and the fan. These modules can be interchanged with other modules within the same family of engines, providing they are all the same specification

2.2 Major Customers (1993)

Table 2- Major Customers 1993

CUSTOMERS	ENGINE TYPES
British Airways (BA)	All (Except BO2)
Pakistan International (PIA)	JT9
American Trans Air (ATA)	JT8
Corsair	JT9
Air Inter	JT8
Gulf Air	RB211 - BO2

Table 2 gives an idea of the type of customers EMMS deal with. This varies continuously depending upon what contracts are won and lost. It must be remembered that a single engine input for refurbishment can cost in the region of a million pounds.

2.3 Overall View of EMMS

EMMS is split up into five separate business units, these being the:
Input, Repair, Engine, Accessories and On-Wing Support. All these units work together to provide the customers with the best 'service' possible for the overhaul and maintenance of aero-engines.

2.3.1 Turn Around Time

A low TAT is required to allow the airline to reduce its number of surplus engines. The airline holds its surplus engines at its airport base and when an engine is dropped off the wing, another one is available to replace it. The engine that has just been dropped is sent to the engine overhaul agency. This means that the airlines stock of serviceable engines has been depleted by one at its base. If the airlines stock is just one engine, and this has just been fitted to an aircraft and another aircraft arrives which has suffered something like a bird strike, or an in-flight shut-down, and the engine has to be removed, then the plane is grounded and an Aircraft On Ground (A.O.G.) situation occurs. This is when an airline is making a very serious loss, with a serious disruption to its schedule.

For the engine overhaul agency the TAT measure starts as soon as it receives an engine. If the airline holds a large amount of surplus engines a zero day TAT can be given. This is because the overhaul agency will hold surplus complete engines, and replace the engine arriving on base with one from stock. This is not a cost effective option with the price for an aero engine running into millions of pounds. There is a definite trade off between the number of engines held and the desired TAT.

For some of customers the TAT is crucial and certain contracts have been virtually negotiated on a guaranteed TAT time. For other customers the TAT is less significant than the cost of the engine service. This tends to be the case for the smaller operators.

2.4 The Input Business Unit (IBU)

The prime function of the IBU is to receipt the engine onto the base, and to then carry out the workscope that is required by the customer. There are three main workscopes:

1) Refurbish

2) Repair

3) Visual

The amount of work done on the engine modules depends on the workscope. For a refurbish workscope the engine can be completely stripped down to a piece part level. All the necessary items are cleaned, all the items requiring crack detection processed and then all the piece parts inspected individually for damage and wear. The amount of work required is reduced for a visual workscope, where the engine modules are in a built up state and are inspected for visual damage only.

TAT times in the business units are measured in engine times for JT9, JT8, Olympus and CFM56 engines, and are measured by the module type for the RB211 engines. The times quoted are for strip to completion of detail inspection. This is when the engine leaves the IBU and is moved into the repair / replenishment section depending on what is required. This is due to the way in which the engines were received. RB211 modules actually arrive as modules, not as an engine, compared to the JT9, JT8, Olympus and CFM56 engines.

The IBU consists of four main sections:

1) The Disassembly / Strip Shop.

2) The Cleaning Bay.

3) Crack Detect.

4) The Detail View Bay.

There are other sections included in the IBU, these include the disc room and powerplant strip. Figure 1 shows the work flow through the IBU.

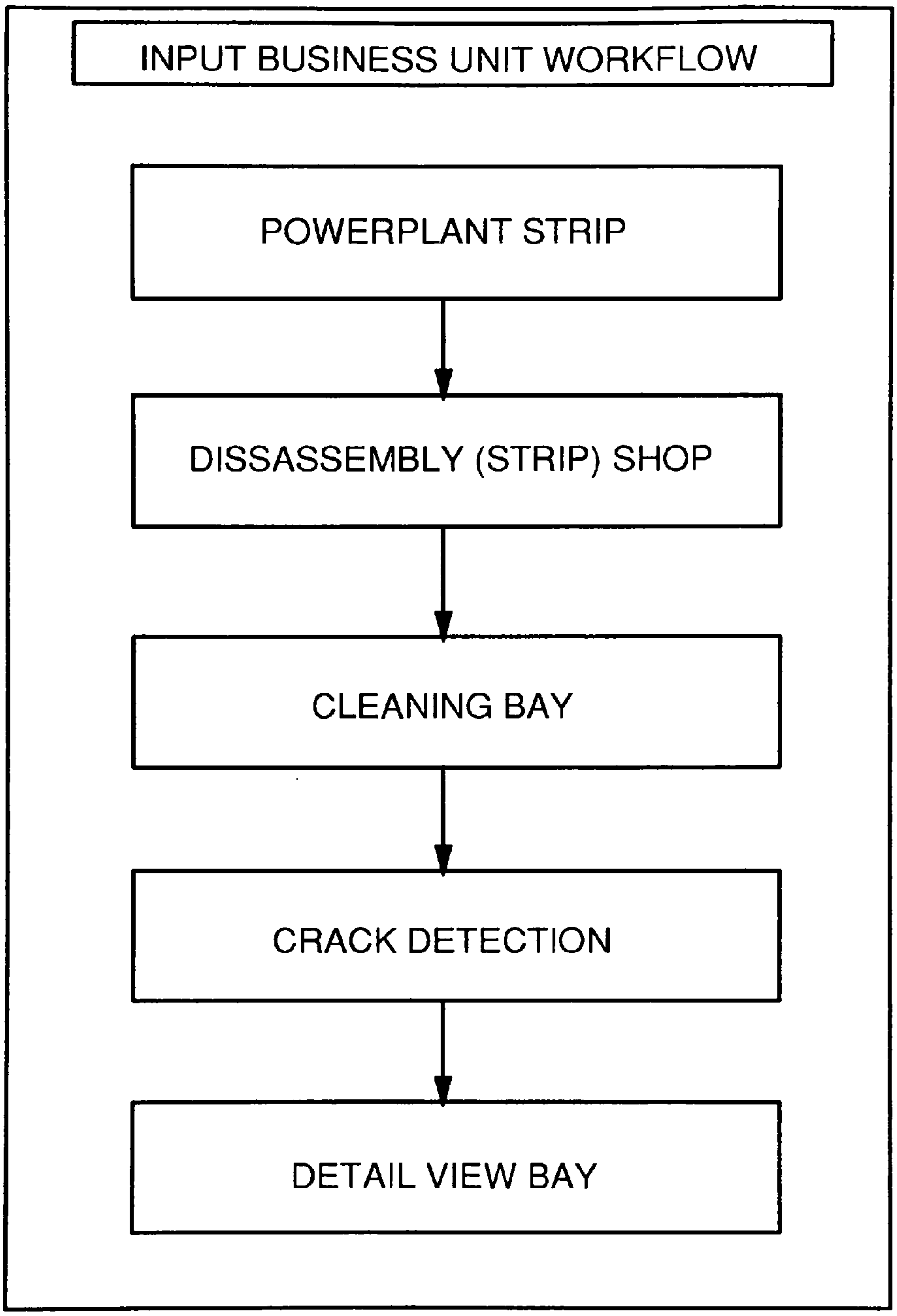

Figure 1. Workflow through the IBU

2.4.1 The Disassembly (Strip) Shop

Disassembly is the first shop in the process of overhauling an engine . In this area the engine is disassembled to the required specification. This could be a complete overhaul or refurbish. First, the engine is bulk disassembled. This is where all the pipes and external components are removed and the engine is split into its separate modules e.g.

Fan, Compressor, Combustion Chamber, Turbine and Exhaust. The next process is to detail disassembly the modules, where every nut and bolt is taken apart ready for cleaning.

During disassembly, engines are worked on both horizontally and vertically using stands and pits. The pits are also used to allow the engines to be raised or lowered to the correct working heights.

2.4.2 The Cleaning Bay

The main function of the cleaning bay is to clean all the engine components and accessories. There are three main types of cleaning- chemical, mechanical and hand cleaning.

Chemical cleaning involves a set of stainless steel tanks containing the various acids and alkalis needed for cleaning engine components. The tanks are kept at pre-determined temperatures and the parts are left in them for the time stated in the engine overhaul manuals.

The mechanical cleaning section is made up of three different types of machine. The dry grit blast machines use aluminium oxide combined with compressed air to clean the components. Vapour blast machines, which are similar to the dry blast machines except instead of air they use water to give a softer cleaning method. The final method being plastic bead blasting machines, which only take the surface debris off the metal e.g. paint and graphite off the base of the blade roots.

Hand cleaning is used on delicate parts and components where grit blasting would damage the surface of the metal e.g. compressor discs and turbine discs.

2.4.3 Crack Detection

This is where all the critical parts as defined in the overhaul manual are flaw / crack detected using various processes such as magnetic particle inspect (MPI) and fluorescent particle inspect (FPI). If any parts require specialist testing such as radiography, ultrasonic or eddy current testing the company has this facility in the non-destructive testing unit.

2.4.4 Detail View Bay

When the components have reached this section they have been disassembled, cleaned and crack detected. The job of the inspectors is to visually inspect the component following the procedure set out in the overhaul manual.

If a defect is found then the inspectors have the power to scrap the part if it is beyond repair or call for repair. They check that the modifications are off the current standard and that the paperwork is correct for the part they are inspecting.

Attached to the detail view bay is a co-ordinate measuring machine (CMM) which is able to measure to an accuracy of two microns. This is used to take critical measurements called for in the inspection process. As a general rule, work is put through the CMM room prior to being detail inspected. This is to prevent unnecessary inspection on parts which are outside of the limits laid down in the overhaul manual.

2.4.5 The Disc Room

This is a specialist area based in the DVB which does specialist inspection work on critical items such as discs and shafts. This work involves the binocular inspection of fir tree roots, with equipment able to take moulds and close-up photographs of areas of concern.

2.4.6 Powerplant Strip

This area of work was based away from the IBU in the health checks area, but has recently been moved down to the strip shop (January 1994). This is where all the external casings of the engine are removed prior to the engine moving onto bulk strip.

2.5 The Repair Business Unit (RBU)

Following detail inspection the engine / module parts are moved either to the repair business unit or to replenishment. The replenishment area is where all the pieces for the construction of an engine / module are accumulated into kits. These kits having all the pieces required to construct the engine. Items calling for repair work to be done are sent to the RBU. This unit deals with all the repairs required, either working them in-house or sending them to sub-contract.

2.6 The Engine Business Unit (EBU)

The EBU consists of the replenishment section and various build lines where all the engines / modules are built. The EBU also has a module change area, mostly for RB211 engines where modules can be removed and another one replaced. Engines, upon completion of build, are sent for test, where the engine is started up and run for a certain period of time and a number of checks conducted on all the engine systems.

2.7 The Accessory Business Unit (ABU)

The ABU deals with all the accessories that are required with the engine. These include all the fuel systems, and electronics that are integral to the running of an engine.

2.8 The On Wing Support Business Unit (OWS)

The OWS unit is situated at Heathrow airport where they are on call 24 hours a day. This is the front line of the business where this unit can deal with everything from removing a customers engine to various amounts of work in situ.

2.9 TAT Reduction Plan - Engine Receipt to Detail Inspection

In mid- 1992 a team was set up to look at TAT reductions in the IBU. This team consisted of all the necessary people from the support functions to give the company members on the shopfloor all the support and information they require to progress the job as quickly as possible.

2.9.1 Objectives

The targets set by the team were :

1) 19 days from receipt of engine to completion of detail inspection by end of December 1992.

2) 11 days from receipt of engine to completion of detail inspection by end of December 1993.

Both these targets would have to be achieved consistently to be of any value (Goldratt 1993). The starting point was an average of 20 days for all types of engine, and fifteen days for RB211modules.

2.9.2 Method

There were two ways to approach this project:

1) To deal with the Input area as a whole.

2) To deal with each shop separately.

The decision was made to deal with each shop separately and to treat them as a set of customer / supplier links. The timescale involved in looking at each shop was given as a week. The first day of each particular week was used to visit the area, and then to immediately carry out an ideas trawl. For each area 'experts' and members of the areas action teams were drafted in as team members.

All the issues affecting that areas TAT were then 'brainstormed,' these ideas listed and ranked under main headings. Each subject was then discussed and agreement reached on the best way to deal with them. All the items were then actioned in one of three ways:

1) Actioned by a team member
2) Actioned by a satellite team
3) Forwarded to the Head of Department for action

Actions 1 and 2 were given timescales for completion. The aim was to have all actions relevant to the section completed by the end of that sections particular week.

The authors role in this project was that of fact finding and looking at improving the workflow through the IBU as a whole. This was also the initial step in deciding whether a simulation exercise was feasible in aiding the project objectives of reducing turn times. Major importance was attached to the fact that the author was new to the facility and could look at the existing process with a fresh set of eyes.

2.9.3 Simulation Modelling

The authors role in this project developed from the initial ideas that were discussed over the use of simulation modelling as an aid to the overall project of reducing lead times through the business unit. Concern was raised over the way in which this project was initially started with the examination of all the areas separately, rather than as a whole. The interface between these separate areas was viewed as critical in the drive to reduce turn times. Any tool that could help to analyse and understand what was actually happening at the interface points would be of great benefit.

It was decided to form a satellite team to look at the use of simulation modelling in the IBU, with a view to making it a long term project continuing after the TAT project team had finished. This will be discussed further in Chapter 3.

2.10 Total Quality (TQ)

The project discussed in this thesis deals with change being implemented in a controlled fashion. To achieve this end it was beneficial to approach many of the problems through the companies existing TQ structure, using the action teams of the areas concerned to discuss ideas and to raise awareness of the change programs being implemented.

2.10.1 TQ Specific to EMMS

TQ was originally introduced at EMMS when it was still part of British Airways in 1990 and again in 1991 when the first launch did not have the full backing of all the company members. This process had continued to evolve through the sell off, and has been continued under the ownership of G.E. There was a dedicated TQ group during the introduction of TQ, but this was disbanded in mid-1993, as it was felt the TQ ethos had gained enough of a hold to be self- sustaining. The reasons for its introduction are listed below (Davies 1994):

* Improved Morale
* Cost Reduction
* Better Solutions to Problems
* Product Improvement
* More Committed Customers
* Reduced Levels of Waste
* Improved Housekeeping
* Continuous Training Programme

The original TQ programme had action teams set up in all areas, each with a budget, and each with the power to implement changes to that action teams specific area, whether it was layout or process. This system then evolved to the advent of the Joint Departmental Group (JDG), where in the case of the IBU this allowed two teams to be formed, one dealing with the disassembly shop and the cleaning bay, the other dealing with crack detection and the detail view bay.

2.11Teams

For specific tasks, teams were formed, bringing together representatives from all the various functions that had an input. This was used to great effect by the 'TAT Reduction Team' (see 2.9). Other areas where teams were utilised was in a simulation team that was formed to support this project.

2.11.1 Self- Directed Teams

The next stage in the advancement of TQ is the move towards self- directing teams. This is the formation of various groups into true self- directing teams (Hughes 1991). At present the current workshop attitude is based on work teams, rather than self-directed teams. To achieve the cultural change for the formation of self- directing teams will probably take four or five years (Irwin, D, Rocine, V. 1994)

CHAPTER 3 SIMULATION

3.1 Introduction

From the exercise carried out in the TAT steering project it was decided to investigate the use of simulation modelling as a tool to aid in the reduction of TAT. The initial target was to analyse what benefits would occur from the implementation of a simulation project. Research was also to be carried out to look in more detail at the use of simulation modelling and how to proceed initially with a simulation project.

After discussion with the simulation team several guidelines were set by the author, to allow the project to be successfully implemented and beneficial. These were seen as the initial terms of reference. These are detailed below:

1) Time scales to be kept to a minimum
2) Cost to be kept to a minimum
3) Must be user friendly (be modified by people with minimal training)
4) Results must be easily interpretable
5) Model must be developed on base (added at a later date)

3.2 Research into Packages Available

There are many types of simulation packages available in the software market today, and many ways of developing models. This can range from having a model completely developed for EMMS, to acquiring a programming language and then constructing a bespoke simulation program. Obviously these two options show the two extremes, both in terms of time and cost. The first one being probably the quickest option, but also being probably the most expensive, while the other option being by far the cheapest, but also the longest in terms of time to implement.

3.2.1 The Choices Available

As Carrie (1988) suggests, there are really four options in which a simulation model could be developed:

1) Write own program in code
2) Acquire a simulation language
3) Acquire a generic simulation model
4) Have model constructed by a consultant

These four options will now be discussed in more detail.

3.2.2 Write Own Program in Code

For this option to be suitable a programming language such as 'C' or 'Turbo Pascal' would need to be bought. The programmer would then need training, and a large amount of time required to construct a model. The major drawbacks of this type of simulation modelling are the time scales involved, and also the complexity of creating an ad-hoc program. The program would also only be useable by people skilled in programming in that particular language, and hence not meet one of the established rules. This would also be the case for meeting the time scales given.

3.2.3 Acquire a Simulation Language

Pidd (1992) demonstrates that packages on the market such as GPSS, SIMSCRIPT, SLAM and SIMAN are languages specially developed for the process of simulation modelling. The major problem with these is that they do still require a large amount of programming, and that they were originally designed to be used on mainframe computers. Again the time scales set would not be achieved with such packages.

Again this type of package would not allow a model to be developed in the time scales set, and would require specialist programming ability not meeting the terms of reference.

3.2.4 Acquire a Generic Simulation Package

Carrie (1988) describes a generic model as a model of a specific type of system written in such a way that certain parameters can be altered by the user through the data. Examples of this include the way a user can define the number of machines working, and the frequency of their breakdowns. These packages allow the user to define all the attributes for the system within the framework given. There are numerous generic simulation software packages commercially available. Examples of these include WITNESS, SIMAN/CINEMA and ProModel.

Major factors for consideration for this type of package are:

1) Cost
2) Hardware requirements
3) Size of model allowed
4) Logic for the creation of the model
5) Output type
6) Training and support
7) Animation

With this type of ready made package the time scales for the construction of the model would be reduced, fitting the time scales allowed. The use of this type of program also allows anyone with a very basic grounding in the use of computers to use the software, as long as they understand the system which they are going to model. Grigson (1992) in her work with 3M describes the benefits of using visually interactive generic simulation packages. 'Cooper has found that people for whom a printout of the results would be meaningless can have presented visually what would happen in their own particular section, even with their own machine, if a particular course of action were taken.'

3.2.5 Use a Consultant

This was the final option considered, and due to the cost involved was never really a serious contender. British Airways Engine Overhaul had commissioned a simulation study in 1990 of the IBU by Warwick Manufacturing Group. This study cost over £10,000, but did not give the results that were expected. One of the major reasons given for this was that the project was carried out away from the base with only infrequent meetings being held to give any exchange of information. As a result the model did not mirror real life. The simulation team agreed that if another simulation exercise was to be carried out it must be done on site. Hence another rule was added to the list of requirements:

The simulation modelling must be done on site at EMMS.

This agrees with the work of West (1992) who states 'however for a large company intending to use simulation over a long term, it would be more cost effective to develop an in-house capability.'

3.2.6 The Previous Model

It was thought that the Warwick model could be installed at EMMS but due to software problems and the reluctance of the consultants to release the model this idea was abandoned.

The first problem was that the software used to create this model was WITNESS, marketed by AT&T Istel. This is one of the most expensive PC based simulation packages available . Obviously, because of the failure of the last attempt at simulation modelling there was a reluctance to spend money on a package, that had not provided the information required or done anything that had proved at all useful. It must be remembered that this period of consultancy also cost BEOL a great deal of money.

Secondly, the time scales involved in modifying an existing model are just as great as creating an entirely new model. The model would have to be completely re-evaluated with all the figures revised to reflect the new working standards coupled with modifications as to how the system was working. The new modeller would also need to understand how the model had been created, i.e. what logic had been used before any modifications could go ahead.

3.2.7 The Simulation Team

After a market survey of available products, it was decided that a team should be put together to discuss the use of simulation in the input business unit. This was to inform the team of the project goals, and to harness ideas from all members of the team. The initial make-up of the team reflected those departments that were going to be affected most by the results envisaged. R.Roy (1986) suggests that 'Visual simulation models help to increase the awareness and understanding of the manufacturing system being studied. This applies equally to the simulation expert and the end user of the study.' The team comprised of the business unit leader, a production engineer, an asset controller, a master scheduler, and the TCA who was going to conduct the project. Other people were drafted in as required.

The make-up of this team was changed as the project continued. This was necessary as people changed positions during the time period of the project. It was essential to encompass members of the IBU who would be directly affected by the findings of the project.

3.2.8 Further Investigation

Following a meeting of the simulation team, where all the above options were discussed with their relative merits and pitfalls, the decision was made to do further research into the packages available, with a view to using a generic simulation package as the tool for the project.

It was in this meeting that the actual objectives set for the model were outlined. Thesen and Travis (1989) discussed the main causes for failure in a simulation project. Of the points listed the key point was not having the aims and objectives of the project defined. This was reiterated in a presentation by AT & T Istel, the suppliers of the WITNESS package, 'Run Tomorrow's Factory Today' (1992). Hence the statement below was incorporated into the project:

'The goal of a simulation project should never be 'to model the.......' Modelling itself is not a goal; it is a means of achieving a goal.'

As a result the aim of the project was set to ***'Look at the present system in respect to scheduling, shift work, queuing and work mix and to then investigate the changes needed to be made to allow the system to achieve a constant TAT of 11 days for all items passing through the IBU.'***

3.3 A Review of the Generic Simulation Packages Available

Now the type of package had been narrowed down to a generic type, it was decided to conduct a study of the packages available to select a suitable package to use on the TAT reduction project. As listed above a checklist was put together itemising the major points as the team saw them. These were:

1) Cost
2) Hardware requirements
3) Size of model allowed
4) Logic for the creation of the model
5) Output type
6) Training and support
7) Animation

Also of interest was whether the package had been developed for a manufacturing process, or whether it had been written as a multi-purpose simulation tool.

This checklist was compiled by obtaining the sales literature from the various suppliers (AT & T Istel, ProModel, SIMAN/CINEMA, SIMFACTORY), and then contacting them if there were any specific questions. Where possible demonstrations were arranged to see the various systems 'in-action.' This was done as a sales demonstration by the suppliers. A table showing the software reviewed is shown in Appendix 1.

The decision matrix was derived from the suppliers literature (AT & T Istel, ProModel, SIMAN/CINEMA, SIMFACTORY) as to what they considered important. Carrie (1988) describes two major factors when choosing simulation software:

1) Ease of use

2) Understanding of output

These two factors were incorporated, but were added after reading the sales literature.

After these demonstrations, the package was discussed by those who had attended, and the good and bad points listed. This formulated the basis of how decisions were made on the selection of a package. Eventually after researching the majority of the major simulation packages on the market, the choice was narrowed down to just two: Pro-Model and WITNESS.

Once the choice had been narrowed down to the two packages, independent users were then contacted. Discussions were held to get an independent view of the two packages. The majority of this information came from a visit organised through the University of Glamorgan to Bath University, where their Manufacturing Systems Department was running both WITNESS and Pro-Model.

This enabled a direct comparison to be made between the two packages, this included the time and skill taken to write a small model, the quality of the animation, and the quality and type of the output. It must be stated that since this exercise has been carried out, the majority of the simulation suppliers in the country have joined loosely together into the 'Simulation Suppliers Consortium', and have been doing various presentations countrywide where all the relevant system have been set up. This allows all the systems to be compared against one another.

All those who had seen the Pro-Model package were impressed with its ease of programming, quality of the animation, size of the model allowed, and the type of output given. The cost factor was very important with Pro-Model retailing for about half the cost of WITNESS and including a student package for use in the manufacturing department. The cost was further reduced by purchasing the system specifically for this project, with the system then returning to the University of Glamorgan upon completion of the two year Teaching Company Programme. As a result of all these factors the decision was made to purchase the Pro-Model system.

3.3.1 Hardware Acquisition

With the software issue decided, it was then necessary to allow for the purchase of a stand alone personal computer (PC) which would be used exclusively for simulation modelling and analysis of the subsequent results. The software gave certain specifications that were needed to be met in order for the system to run. It was decided that the 'faster' the PC that could be bought the easier the running of the model would be, especially as a large model was envisaged.

After consultation with the system department of EMMS, it was agreed that a 486/50 machine would be powerful enough to allow the package to run and be able to cope with any size of model produced. It was also decided that model storage might be a problem, so the PC specification was upgraded to include a tape driver, which could be used to store large amounts of data.

3.4 Training in the use of Pro-Model

With the purchase of Pro-Model, a 3 day training course was included at Pro-Model in Warwick. After consultations with the simulation team, it was decided that it would be better to attend the course not as a complete novice, but with a certain amount of knowledge of the system, so it would be better to go and ask relevant questions as to how to overcome certain problems. As a result a month, was allocated for the modeller to get to know the system and to get some-way into building the models required, before attending the training course.

The first version of Pro-Model acquired, was DOS version 5, this came with a series of demonstration models which could be used to look at the various constructs needed to make a complete model. Going from a very basic syntax into a very complicated combination of steps to achieve the desired effect. Later versions mean that the present version is DOS version 6.

3.4.1 The Pro-Model Package

A systems overview of the ProModel system is given in the ProModel Manual (1993) *'Pro-Model (Production Modeller) is a powerful yet easy to use PC based simulation tool for modelling all types of production systems ranging from small job shops and machining cells to large mass production and flexible manufacturing systems.*

ProModel PC offers the convenience of a menu-driven, non-programming modelling environment and the flexibility of a general purpose simulation language in one easy-to-use program. At the same time, ProModel PC is easy to learn and can reduce model developments and debugging time by weeks and even months.'

Figure 2 represents the outline of a typical simulation project.

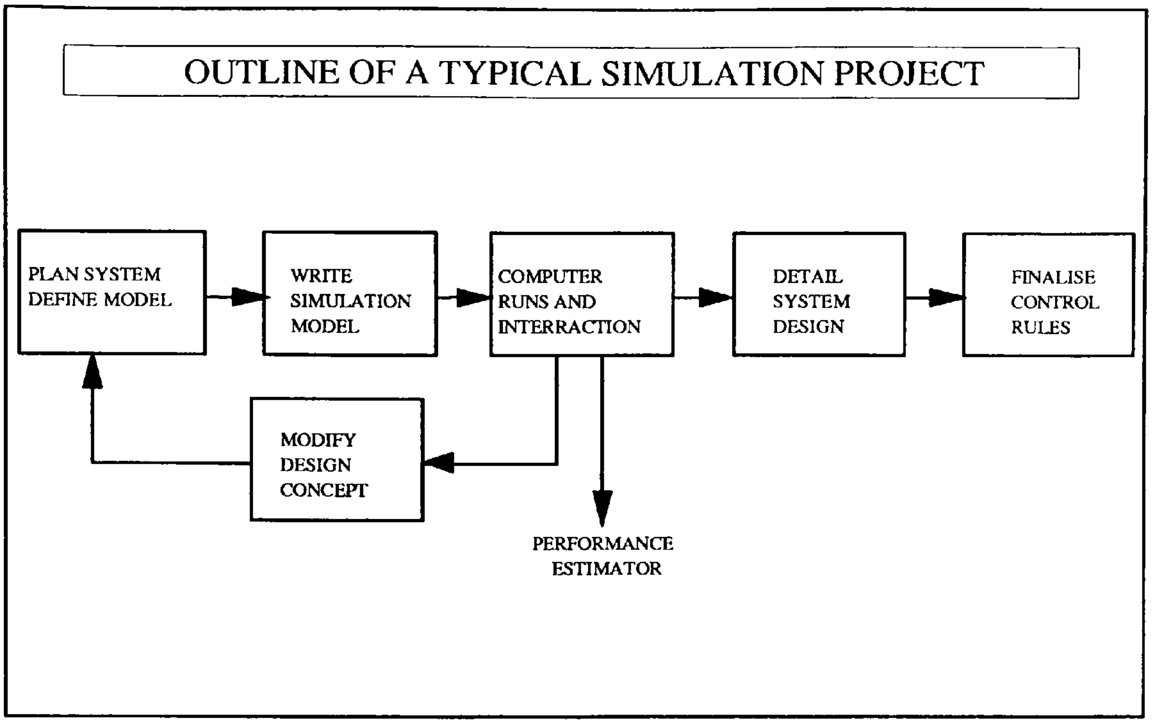

Figure 2. Outline of a Typical Simulation Project

Modelling Orientation

A description of the Modelling Orientation is given in the ProModel PC Manual (1993) *'What makes ProModel easy to use is the simple and straightforward way in which models are built. Defined in much the same way one would naturally describe a production system, a models structure is entered into the program using familiar terminology. The modeller begins by defining the flow of parts through the system, location by location, specifying what operations if any, are performed at each. A location can be a machine, work station, storage site, queue, a position on a conveyor or storage path, or an entire department.*

Once the routing for each part type has been defined, the modeller schedules the arrival of parts to the system, specifies resources, capacities and addresses any special operating or downtime characteristics of the resources being used. Each of these tasks is performed using easy-to-complete modules that are automatically linked by information supplied in a previously completed model. If the modeller elects *to show animation, the program walks him through additional modules to develop a layout of the model.*

As an alternative to first defining the part flow logic, the modeller may even begin by defining the system layout before addressing part routing, scheduling, etc..'

3.4.2 Use of Small Models

When approaching the task of modelling a large system, such as the Input Business Unit, it was decided easier to split the system into four separate blocks which could then be joined together. These being the strip shop, cleaning, crack detect, and the detail view bay. These splits representing the splits of the shops in the unit.

It was also decided that the syntax of the engines / modules passing through the area would be very similar. Thus the initial goal was set at achieving the correct syntax for each of these areas, and then expanding the syntax to encompass all engine and module types.

3.5 Data Gathering

The most critical point of any simulation exercise is having correct data to start with. If the data used to model is inaccurate then the results will be worthless as the simulation model will not represent the original system: *'Rubbish in, equals rubbish out.'* Also to be decided was at which level to carry out the modelling.

3.5.1. Modelling Level

It was discussed in the simulation team, what level the model should be targeted at. The options available were:

1) Piece part level,
2) Module level,
3) Engine level.

The idea of modelling at piece part level was not really considered an option due to the amount of work involved in the data gathering. Due to the variety of work going through the system there would be thousands of individual piece parts, which could be grouped together to provide larger modelling entities. Option 3 modelling at engine level was again not really considered viable because of the workscopes applicable to engines passing through the IBU. In the breaking down of engines into modules, some modules can have completed the whole process, whilst others are still being stripped. This left option 2 , modelling at module level. The simulation team felt that this level would provide enough detail to be able to analyse any effects that changes to the system would make. It would not require large amounts of time to be spent data gathering and producing the simulation model.

3.5.2 The Data Gathering Process

The first stage in this process was to actually identify what data was required. This was split into two different types of data. The first, being the times taken for the module in each of the shops, given the capacities available, and the manpower available. These are the times that the modules can take given the availability of the variants. The other times taken were for the actual times the modules / engines were taken to complete the whole of the Input Business Unit. There were some basic rules set for these times. RB211 modules were to pass through the system and be measured as separate modules. Engines were to be inputted and broken down into modules which then flow through the system, and are then accumulated back into an engine when all the modules are there, this being the time measurement taken.

The data gathering regarding capacities, manpower and process times, was more difficult. This actually required the measuring of times on the shop. The first step was to get the standard man-hours which are used for job costing in each of the areas. The problem with these figures being that they are man-hours and do not give any idea as to how many men worked the job or any idea of the process times given. These figures were then discussed with the supervisor of each section to get feedback as to how they felt the figures compared with what actually happened, the standard time figures were then modified. This discussion with the supervisors also allowed the modeller to ask questions as to the workings of the system e.g. priorities, order of work, number of men used, training, capacities. This information was then used to construct the individual models of the areas.

An example of the data used to construct the model is given in Table 3, and a full listing of all the data used given in Appendix 2.

Table 3. Example of Data Used to Construct the Simulation Model

Cleaning Bay

(All times given are total manhours)

Engine JT9	Tank Times	Machine Times	Hand Times
A	3	4	2
B	8	3	2
C	6	7	2
D	6	11	2
E	2	0	4
F	2	0	4
G	1	5	2
J	6	3	2
K	6	0	2
L	6	1	2
V	4	3	2

The other figures collected were the total times taken for engines and modules to pass through the system. These figures were used as a benchmark from which the model representing where we are now, and from which all the 'what-if' scenarios can be compared against. These figures were used to evaluate all the models. Fortunately, this TAT data had been collected earlier in the year so there was a significant amount of data from which to base frequency evaluations. A listing of the actual TAT figures is given in Appendix 3.

It was at this point that the simulation team decided it would be beneficial for the modeller to be sited on the shop floor. This was a seen as necessary to allow the modeller to be able to question the system running and also for him to be accessible to the company members on the shop-floor. With this move to the shop floor a number of demonstrations were given of the simulation package and the purpose of the exercise explained. These demonstrations were continued as the model progressed with presentations being given to all those who showed an interest in the project.

As the model progressed it was noted that more and more detail needed to be added to areas of the model. This was particularly seen in the models of the detail view bay, and the strip shop where training / skill levels were required to be added. Work could be queuing, if there was no-one available with the right training to pick the work up as required. The model was continually updated so as to bring it into line with the way the actual system behaved.

Other information that had to be gathered included the time between inputs of engines and modules into the system. This was transferred into a frequency diagram, which was then built into the inputs for the model. These tables gave the time between inputs figures. These are shown in Appendix 5. Also included for this was the elapsed time for the engines / modules to be loaded into the shop. There were many iterations until the base model was felt by the simulation team to accurately represent the real world scenario.

As the model was going to be built using a module level as the base level, information was needed on how many modules each area could hold, and effectively work on. This information was obtained by discussions held with the supervisor / team leader of the area, and then the company members working in this area

3.6 Conversion of the IBU into a Simulation Model

An example from the simulation programme is shown in Figure 3. A full listing of the programme used as the base model is shown in Appendix 4. This base model is the culmination of many smaller models which were integrated. The iterations were carried out in the programming stage where areas were identified that were unrepresentative of the real world scenario.

JT9	OUT	1::	JT9	PIT	0	1	0
			DOWN9	MAN2	0	3	0
JT9	PIT1	1::	JT9A	DS	0	1	5::
			JT9B	DS	0	1	5::
			JT9C	DS	0	1	5::
			JT9D	DS	0	1	5::
			JT9E	DS	0	1	10::
			JT9F	DS	0	1	5::
			JT9G	DS	0	1	5::
			JT9H	DS	0	1	5::
			JT9J	DS	0	1	10::
			JT9K	DS	0	1	5::
			JT9L	DS	0	1	10::
			JT9V	DS	0	1	10::

Figure 3. An Example Listing from the Base Model

The modelling of all the areas in detail will be discussed with the aid of Figures 4,5,6,7 and 8.

3.6.1 The Bulk Strip Process (Figure 4.)

Figure 4. shows the process used to simulate the bulk strip process. An engine is inputted into the system. A number of men (resource) work on the engine to split the engine down into a series of modules. The time element used to model this process is that of using a movement time (variable) coupled with use of resource i.e. pits, men. This allows for the modules to be released from the engine in the correct order. It is

feasible for a module to be two processes further down the system before the whole engine has finished bulk strip.

Figure 4. represents in a diagrammatic way the process used to simulate the bulk strip process. An engine enters the shop, is worked on by a number of men, and is split into a number of modules.

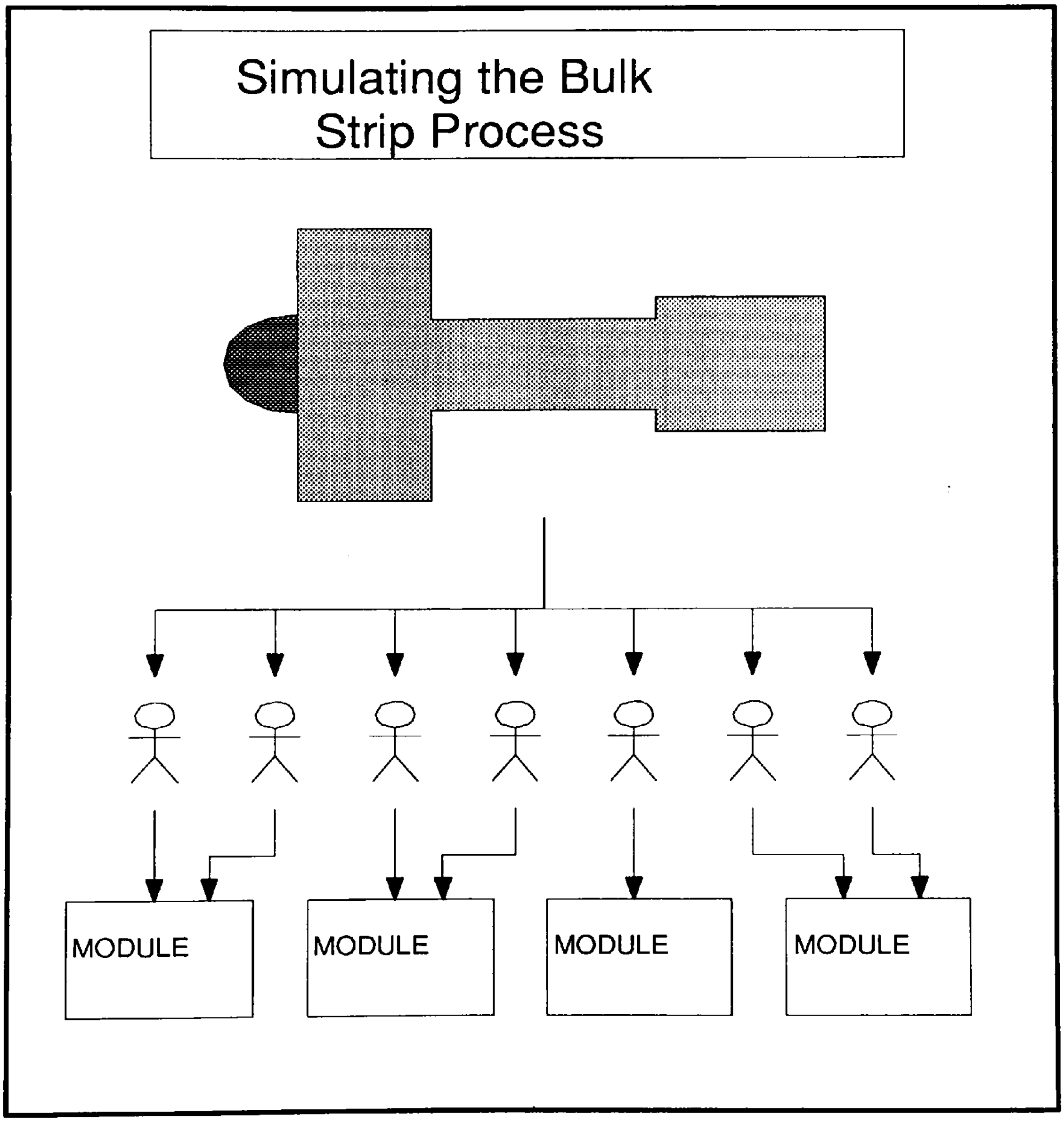

Figure 4. Simulating the Bulk Strip Process

3.6.2 The Detail Strip Process (Figure 5)

The Detail Strip Process is the complete breakdown of the module into piece parts (this collection of piece parts is still referred to as a module). Figure 5 shows the way in which the simulation model was created. A module arrives and requires a certain number of hours work to be completed before it can pass to the next process.

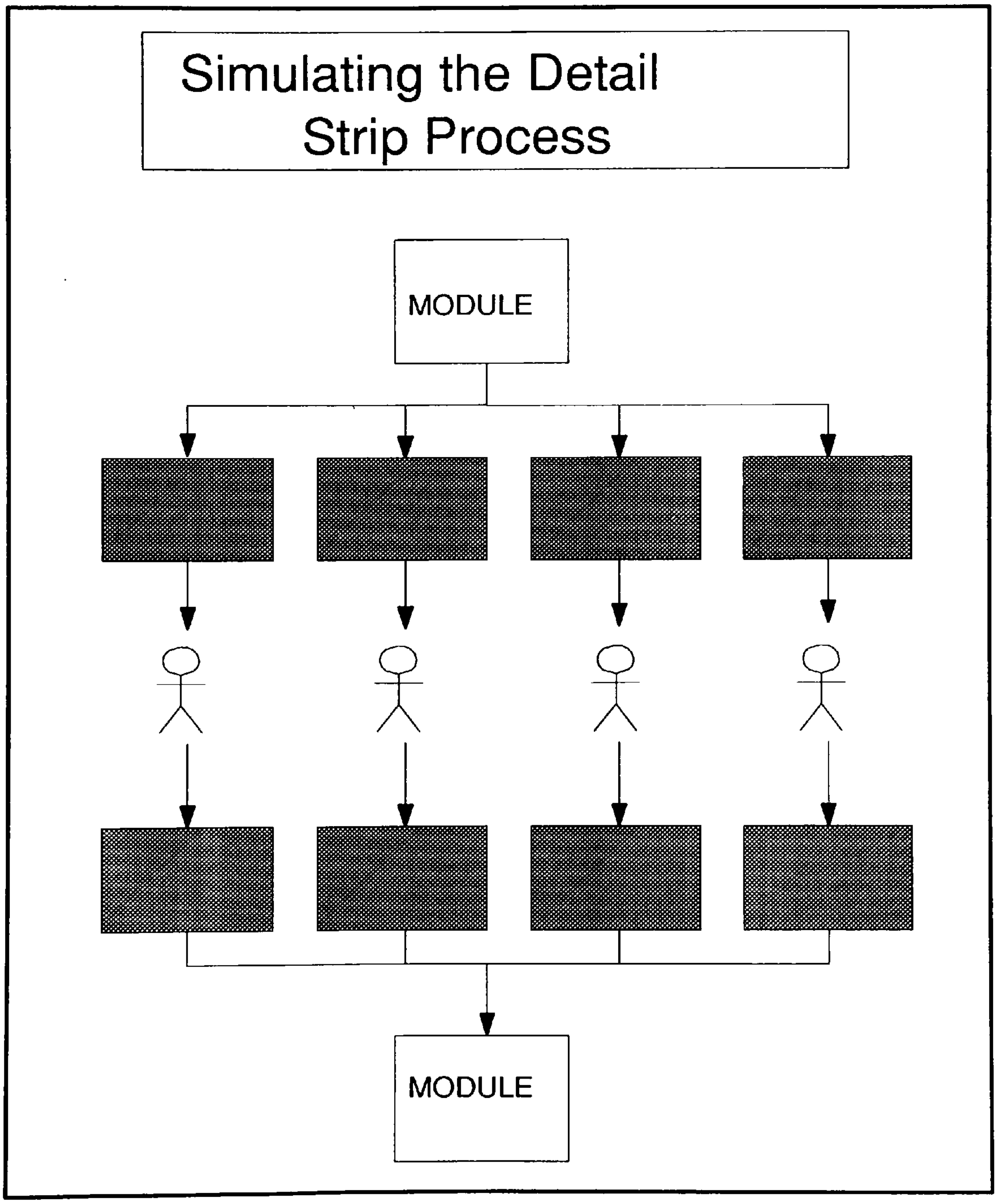

Figure 5. Simulating the Detail Strip Process

To model this, the module arrives and is split into the number of hour work units required to be completed. These work units are then held by the appropriate resource (men with correct training) for an hour. These work units are then accumulated until all the specific work units for that module are complete. The module is then deemed to have finished detail strip. This technique was used in modelling other areas such as the detail view bay.

3.6.3 The Cleaning Process (Figure 6)

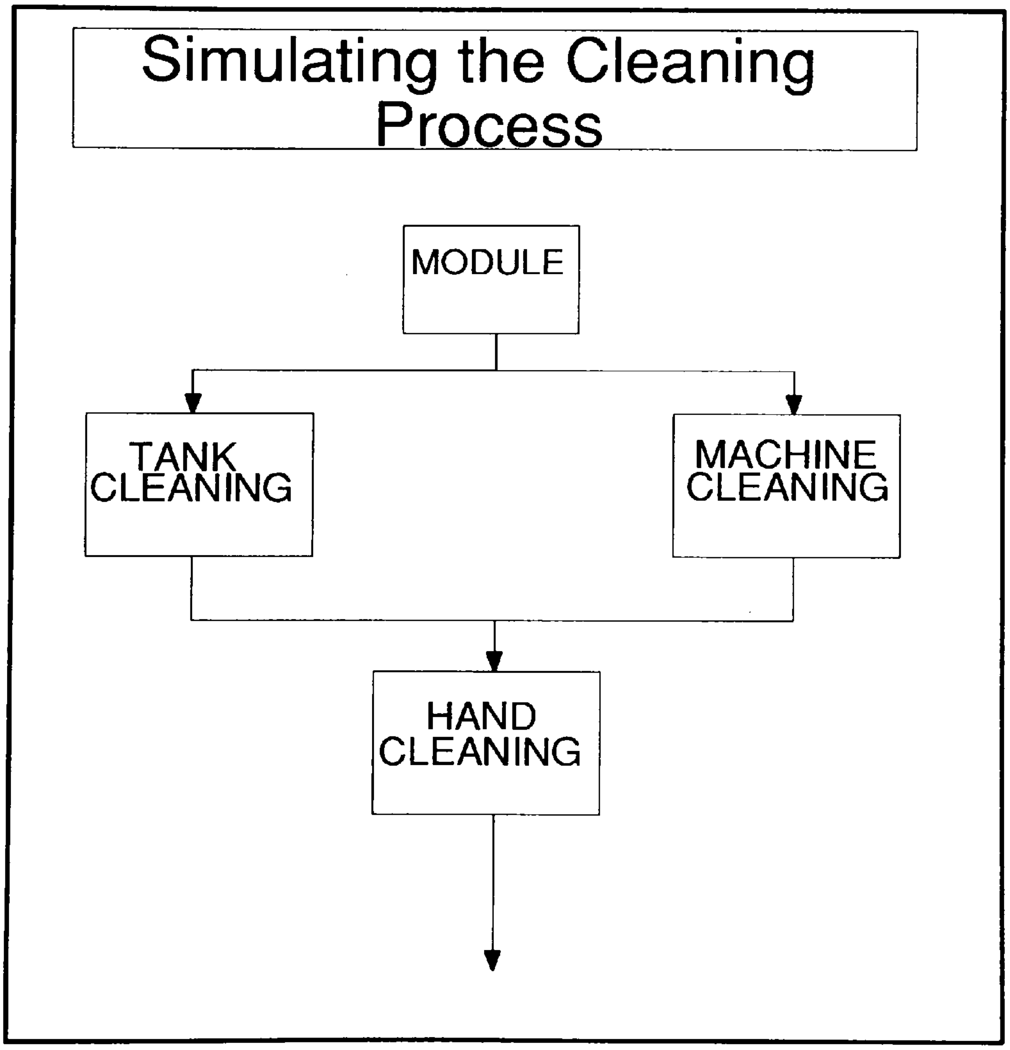

Figure 6. Simulating the Cleaning Process

There are three processes which the modules might have to pass through depending upon which module is being worked. The general order is that tank and machine cleaning are concurrent and then a hand cleaning process is used. Depending upon the process requirements the module can again be split into two, and the time required to process each part of the module worked on concurrently. The two parts of the module are then accumulated and the module goes for hand cleaning. After this process the module has finished the cleaning process.

3.6.4 The Crack Detect Process (Figure 7)

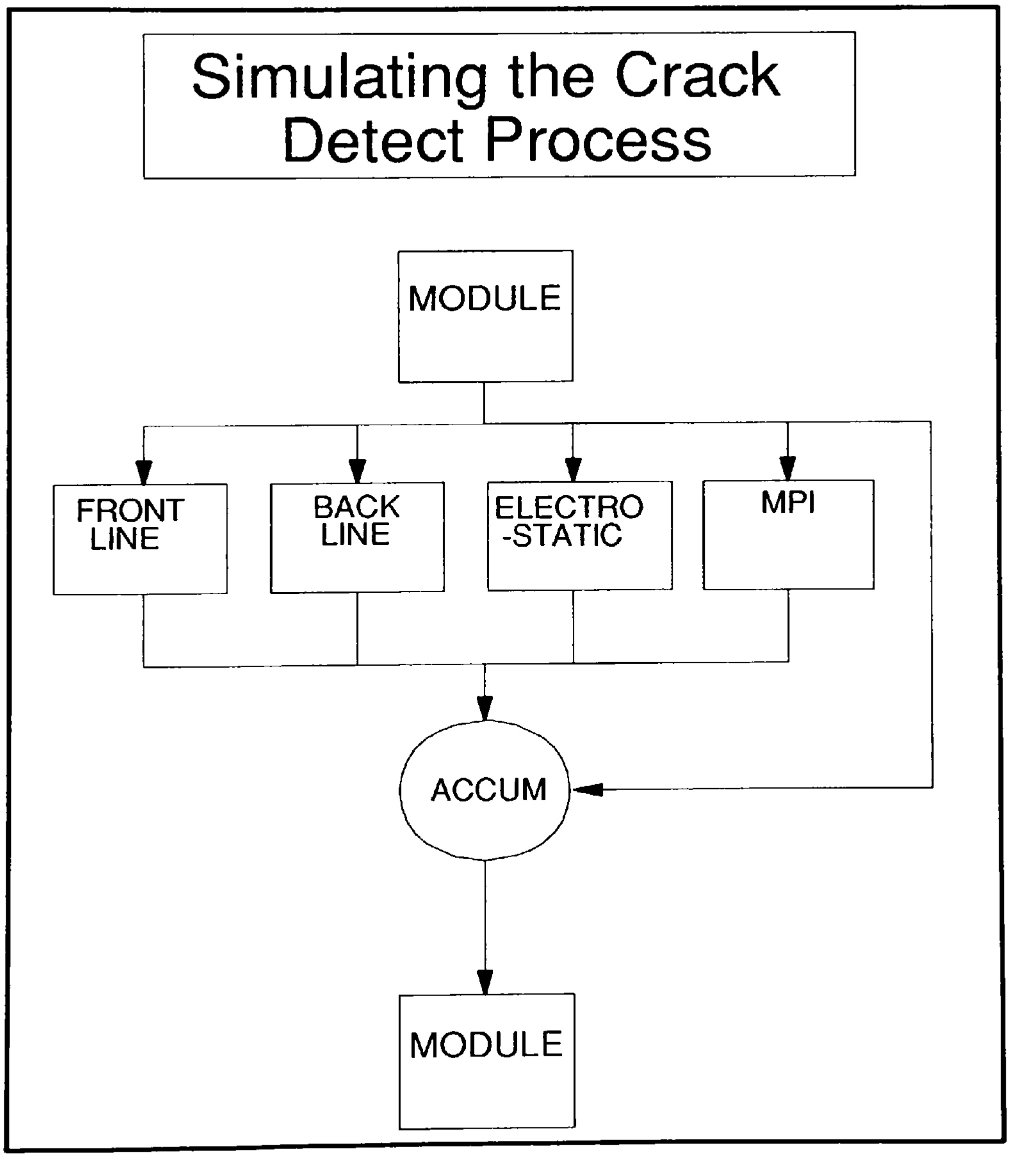

Figure 7. Simulating the Crack Detection Process

This process is very similar to the cleaning process, where the module is broken down into the parts requiring the types of crack detection that are available. The four processes available are front-line crack detect, back-line crack detect, electrostatic crack detect and MPI (Magnetic Particle Inspect). The cube containing these piece parts is used as a base, and the parts that have gone from crack detect are accumulated back onto the cube.

3.6.5 The Detail Inspection Process (Figure 8)

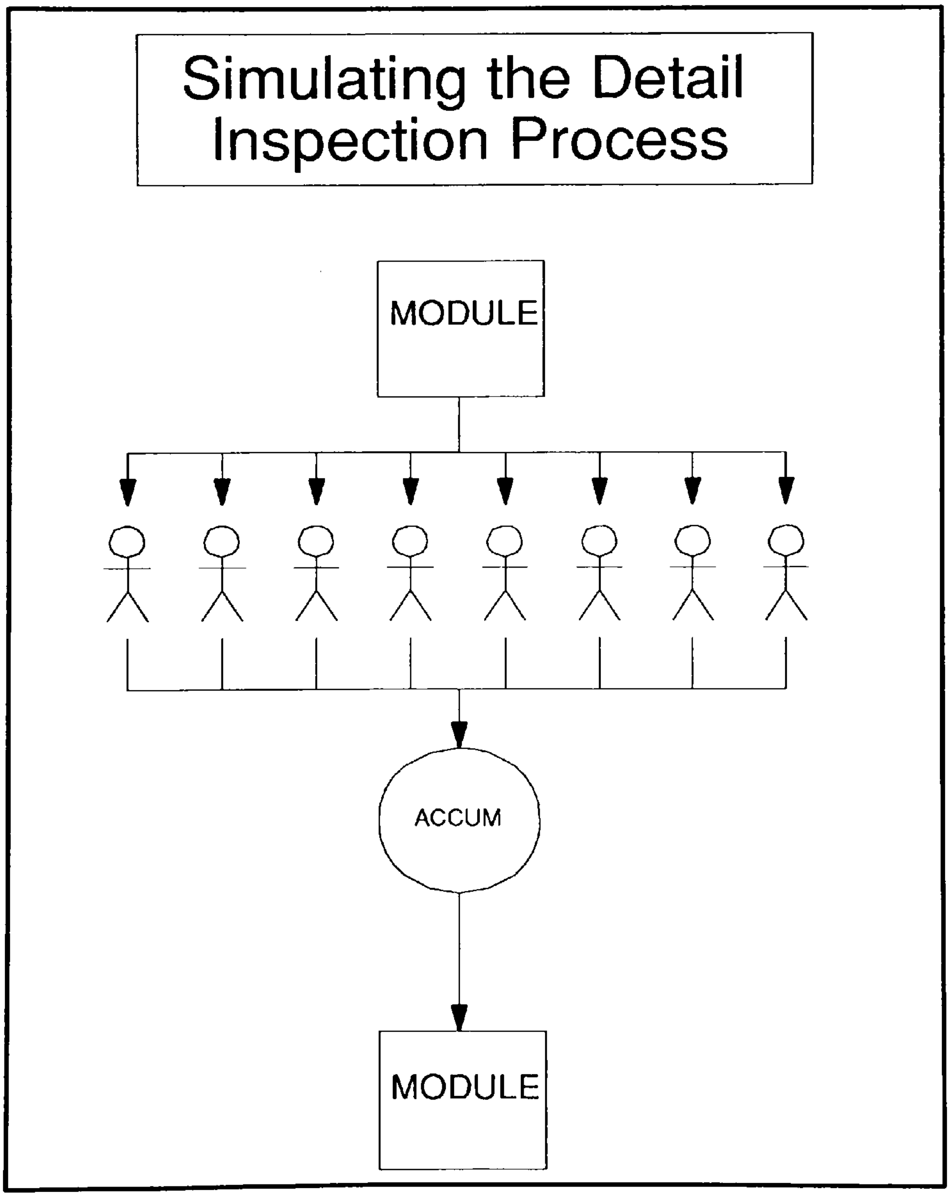

Figure 8. Simulating the Detail Inspection Process

The module arrives at the detail view bay and is split into a number of sections, e.g. the JT9 B module is split into two sections, the static's and the rotors. Each of these sections has a certain number of hours work associated with it , which can only be done by someone who has been trained on the module. Once these sections have been finished they are accumulated together into the module and the detail inspection process is finished.

Once a module has finished the detail inspection process it waits until the rest of the modules associated with the engine inputted are finished, and is then accumulated into an engine.

3.6.6 Time Logging in the Model

There is a formula set up in the model that records the time from input to completion of detail inspection. This was used to track the TAT times generated by the model and to compare them against the actuals that had been collected. This logging of TAT times was also used when the model was experimented to generate 'what-if' models. Times were also logged of every module passing through each section of the system. This was again used as a check to make sure all the times generated by the model were realistic.

3.6.7 Time Counter

Initially a real time counter had been installed to visibly show at what time of day the processes were operating. This was used to check the shift downtimes compared to real world times. This was left in for early iterations of the base model but was later removed when the 'what-if' evaluations were run. This was due to the amount of time taken for a counter to run on screen when dealing with a large system i.e. every hourly iteration was taken into account when running, so for a year long run, a huge amount of memory was used.

3.6.8 Run Time

The model was set to run for a period of one year, allowing the equivalent of three months for the model to actually settle down into a steady state. It was after the three months that data was used for analysis and comparison.

3.6.9 Shift Times

Shift / operation times are included for all areas of the model to simulate the shift system that the IBU runs. This was modelled in a variety of ways, ranging from the manpower that is used to the machines being given downtimes to represent the shift times. This is particularly relevant for the strip shop and the detail view bay where the areas are manpower dependent and training is crucial to the running of the business unit.

CHAPTER 4 VALIDATION OF THE MODEL

4.1 Validation

In order to move onto the next stage of modelling it was necessary to prove the validity of the model that had been created against the real world system. This can be seen in Figure 9.

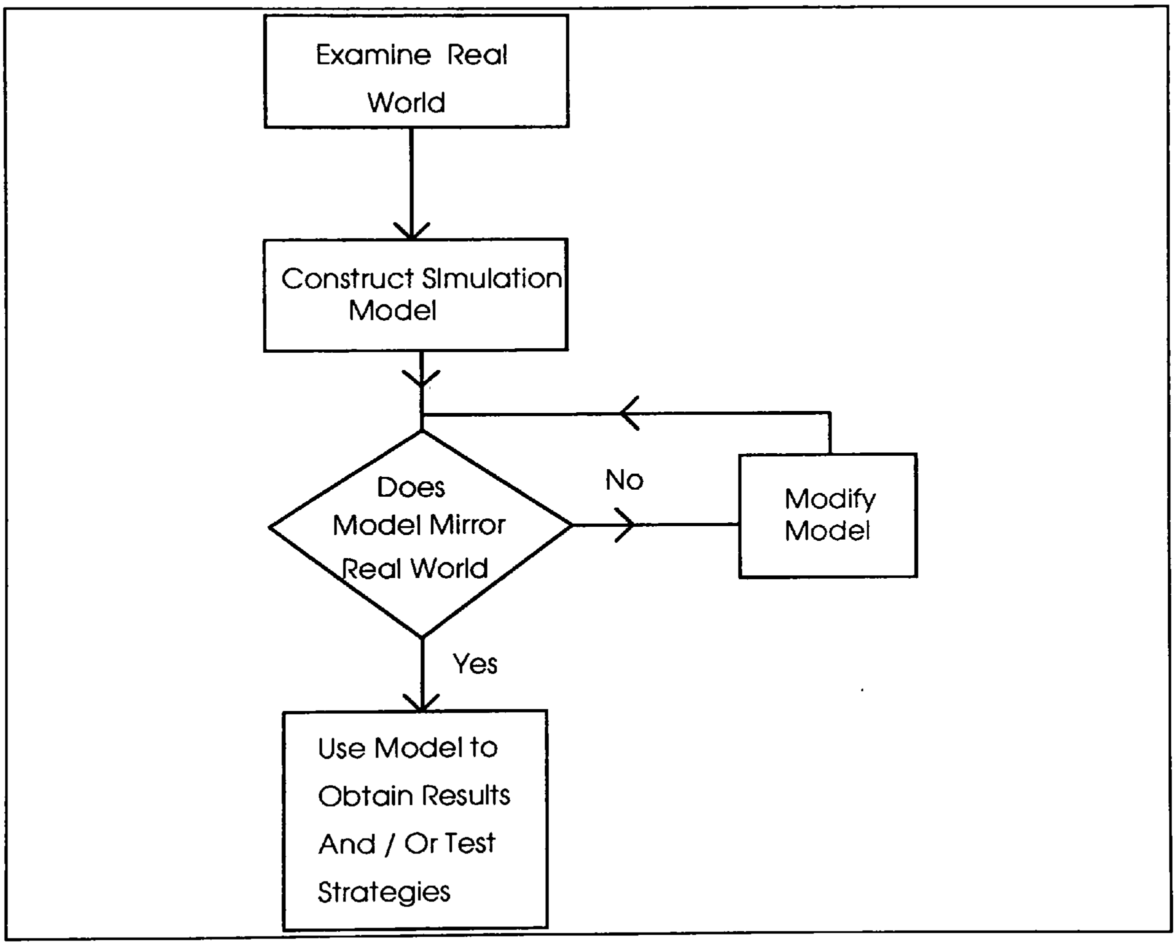

Figure 9. Flow Diagram Showing the Construction, Testing and Use of a Simulation Model (Smith 1970)

In doing this it was required that some sort of benchmark be set whereby the results generated in the simulation model could be compared with relevant actual results from the real world. TAT measurements for engines and modules had been collected for many months in the business unit, and it was decided to use these TAT figures /

distributions as the base figures and then to compare the simulation results against these. This would give a very good indication of the validity of the model.

The total number of engines passing through the system was a figure taken from the results of the previous year and also a forecast given for the coming year. Though these actual numbers were not actually used in the model, a distribution was set up to give a 'time between arrivals' (TBA) distribution. This was a frequency of the time between each engine arrival, that is the number of hours between each engine input. An example of the frequency charts generated is shown in Figure 10. All the frequency charts are shown in Appendix 5.

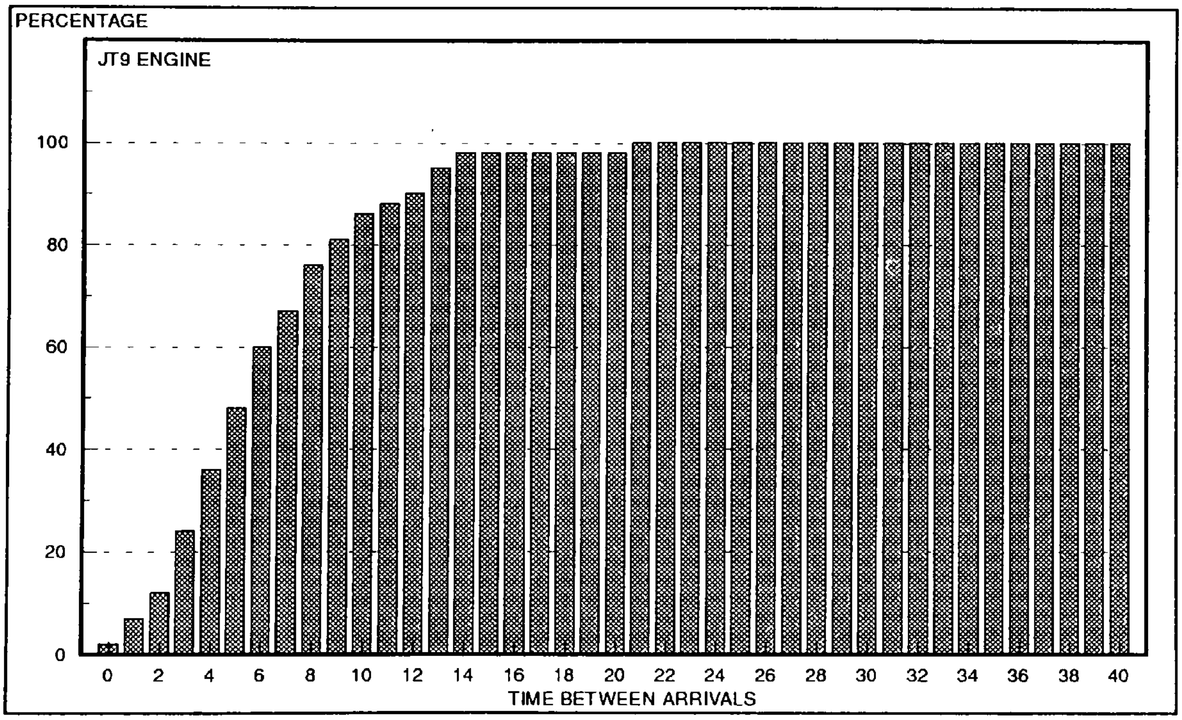

Figure 10. Frequency Chart Showing Time Between Arrivals for JT9 Engines

The comparison of the actuals compared to the model were generated from TAT times that had been collected over a six month period. These were then compared against the six month actuals and the charts plotted again, one for the first six months and one for the last six months. An example chart is shown by Figure 11. All the charts are shown in Appendix 6.

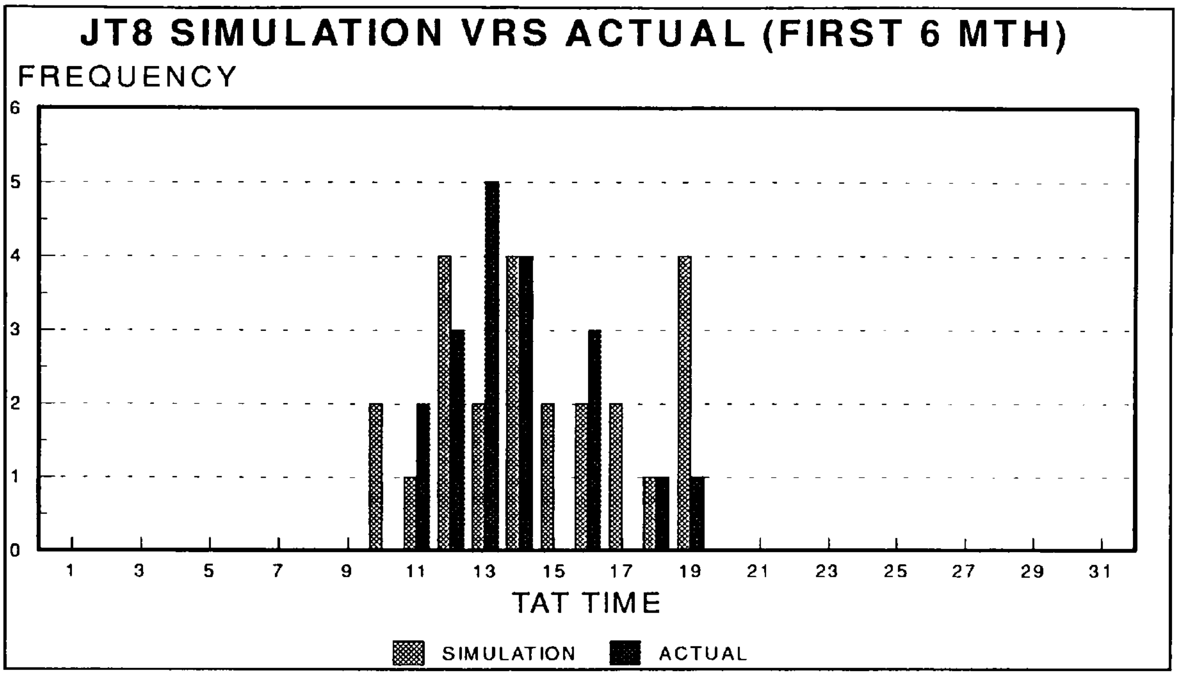

Figure 11. JT8 Simulation Results Versus Actuals (First 6 Months)

4.2 Analysis of the Resulting Distribution

It must be remembered that the results produced from the simulation will not mirror the real world situation exactly, but will mirror the general trends of the real world system. The distributions that will be discussed below, were taken to the simulation team for examination. Here the simulation results were compared against the actuals and a subsequent discussion as to whether the results were felt to be realistic.

During the time period over which the simulation model was being created there was a very slack period of engine inputs. The affect this had on the actuals is to reduce the amount of work-in-progress (WIP) and hence the TAT on all the engines / modules that are passing through the system. Hence, when discussion was conducted to validitate the simulation model results against the actual historical data, some assumptions had to be made to allow for the slack period.

JT9

The simulation results generated for this engine reflect very accurately the real world results. The simulation distributions ranging from 10 to 19 days with the actuals for the first six months ranging from 11 to 19 days. Both the simulation and the actuals peak at the 13 / 14 day mark. That is the majority of engines put through the system take 13 / 14 days to complete strip to detail inspection.

Olympus

The historical data for this engine only has a record of 7 engines entering the system. This does not give a fair representation as to what would actually happen, so some assumptions were made from historical information as to the TAT of this engine. The limits for the actuals being 13 to 21 days, compared to limits of 14 to 21 days for the simulation model. The actuals peak at a TAT of 16 days, compared to the simulation models 15 to 17 days. The results generated by the simulation model were felt to be accurate enough to warrant further work. The time delay waiting for further Olympus engine inputs would be far to long to wait to continue to validate the model.

JT8

A similar problem to that seen on the Olympus was experienced in trying to examine the JT8 situation, due to the fact that during this time period there were only four inputs. This situation was again looked at with assumptions having to be made based on historical trends as to the number and frequency of inputs. The TAT range generated by the simulation model gives the figures 9 to 22 days, compared to the actuals 9 to 21 days. The peak generated by the simulation model is on the 14 days TAT. Since these actuals were used JT8 work has significantly increased, and is now the second largest contract at EMMS.

RB211- 01

01 Modules tend to have the lowest TAT of the RB211 engine modules due to their size and work package. The actuals range from 3 days to 25 days. The majority of the range lying between the limits of 3 days to 11 days. The simulation results also reflect this diverse trend, ranging from 3 days to 17 days, though the majority lie in between the 3 day and the 14 day marks. The frequency peak for the actuals is on 9 days compared to the simulations frequencies of 8 days and 13 days peaks. Again in discussions with the simulation team it was felt that the results generated from the simulation model were accurate enough to work with.

The 25 day times were generated by modules where problems were experienced in identifying the module, deciding upon a workscope and waiting for customer decisions once the module had been stripped.

RB211- 02

There were significant numbers of 02 modules passing through the system giving enough data not to require assumptions. The actual range varied from 6 to 23 with the simulation results having limits of 7 to 24. The peak for the actuals being 11 days, with another peak at 17 days. The simulation results peak from the 11 to the 18 day limits. These results were considered accurate enough to allow progression of the simulation model.

RB211- 03

The RB211- 03 module has a very diverse range of TAT, the actuals ranging from 4 days to 20 days, with the vast majority being in the region of 7 to 11 days. The simulation results have the limits of 6 to 18 days, with the peaks being in the 10 to 15 day region. Discussions with the simulation team felt that again this was a justifiable distribution. Looking at the actuals and also the work throughput for the beginning of the year which was surprisingly short of engine inputs compared to module inputs, it was felt that these results were suitable for any form of what-if modelling.

RB211- 04

The 04 module has a very wide actual distribution ranging from 1 to 24 days. The simulation model ranged from 9 days to 22 days. The very quick TAT for the actuals is due to modules with a special workscope. This leaves the modules in a built up state with a minimum of strip, cleaning, detail inspect and no crack detect. The modules with the special workscope were felt to be such a rarity that they were ignored in the simulation model. The distributions for the simulation were very close to the actuals and were felt to be very representative of how the system operates according to 04's.

RB211- 05

There were enough throughputs of this module to allow for a distribution to be plotted. The actuals ranging from 4 to 20 days, with the simulation ranging from 6 to 21 days. Though the peak for the actuals was the 7 day period. The simulation model actually predicted the majority of modules taking from 11 to 15 days. This discrepancy was due to the actual figures being taken at a time where there was very little work in the shops, and so labour was concentrated on any work that was there. Again this was brought to the simulation team for attention. The results were considered accurate enough to progress the simulation model.

RB211- 06

Initially the 06 module workscope only required strip to crack detection and no detail inspection. In early 1994 the detail inspection for the gear boxes was moved to the detail view bay from the sub-assembly area. Again discussions were held with the simulation team to verify the results. The results generated were felt to be accurate enough to be used to experiment with the system.

4.2.1 Validation Problems

The validation phase of the model took far more time than had been originally planned. This was partly due to the desire of the modeller and the simulation team to get the simulation model to match closely the actuals that had been recorded.

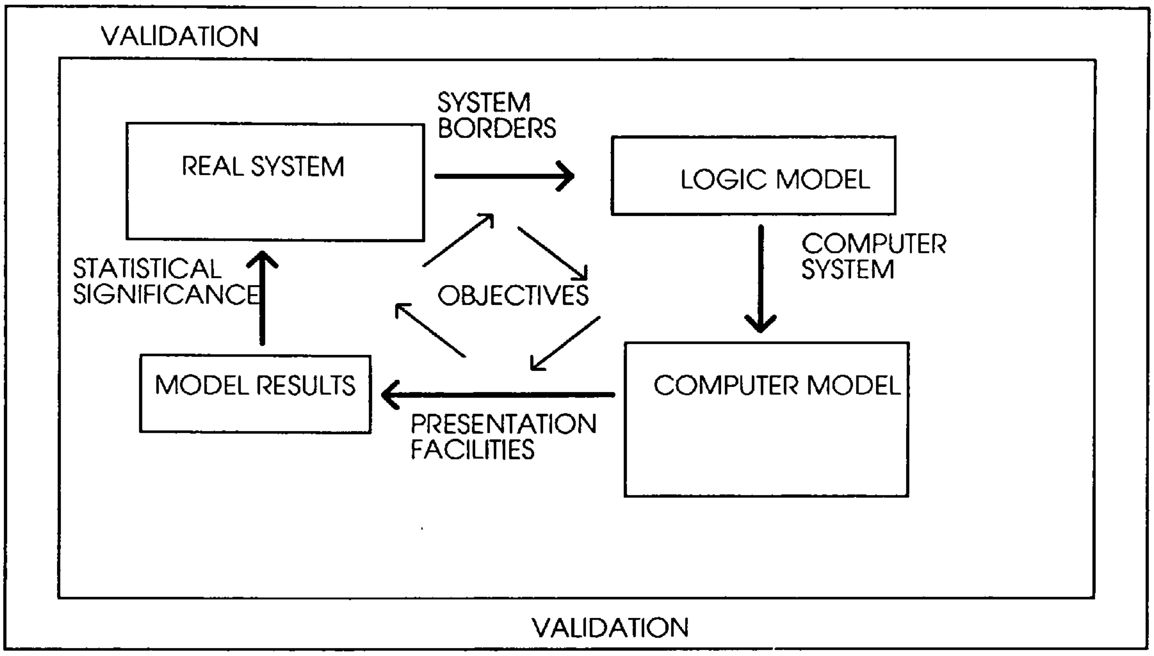

Figure 12 The Objectives Influence Heavily on a Model's Validity

A great deal of time was spent 'tweaking' the model so as to modify the results given. J Strandhagen (1989) in his diagram (Figure 12) shows how the validation phase sits around the whole of the simulation exercise, and how the objectives of the project influence the validation of the model.

This 'tweaking' was done mainly in varying the times the module spent in various areas of the shop. This was done in discussion with the supervisors of the sections so as to maintain the validity of the model. After every tweak, the model was run and the results analysed and compared to the actuals that had been recorded. Even with these small changes in the system the difference to the final results was visible. These changes were measured through a system which allowed TAT to be collected across each of the areas and analysed against previous runs.

4.3 'What- if' Modelling

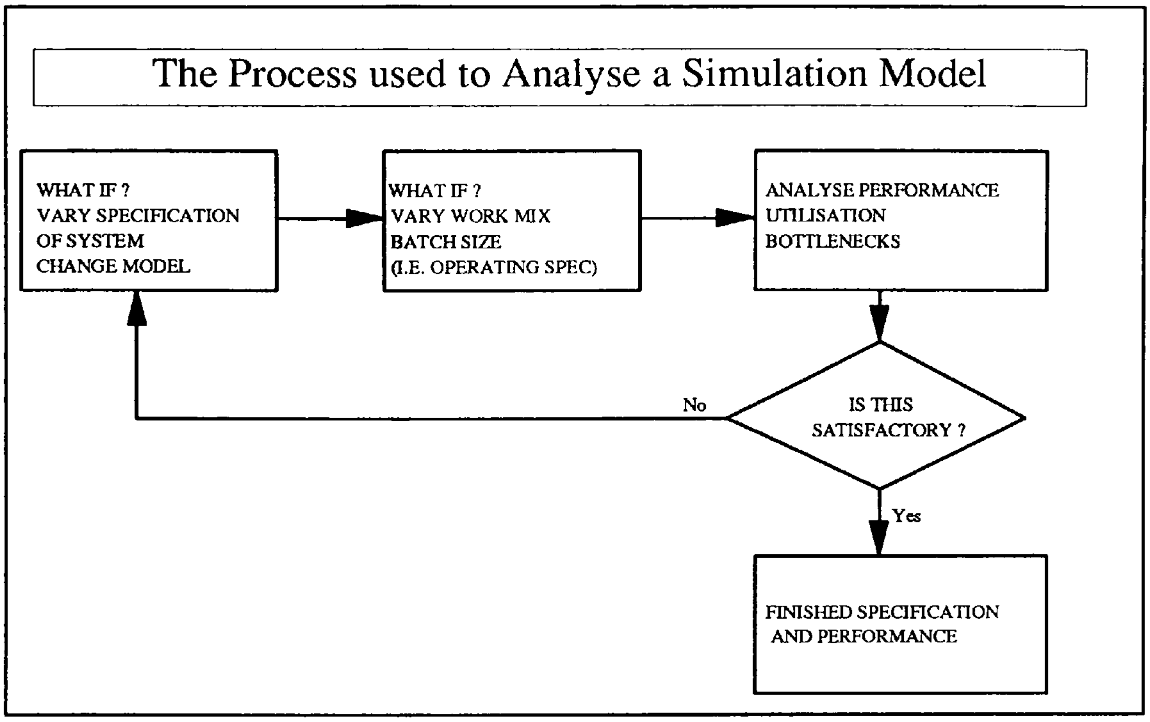

Figure 13. The Process Used to Analyse a Simulation Model

After the validation phase the model was felt to accurately represent the real world system. The next stage was to move to the 'what- if' modelling. This was where the true value of the model would be established. Changes to the system could be tried and examined, and the throughput of the IBU could be examined without actually making any of the changes to the real world scenario. Figure 13. shows the process used to analyse the simulation model.

The simulation team had a preliminary meeting to discuss how the 'what- if' modelling should be organised and how the differences should be measured. It was at this point that one of the benefits of the Pro- Model system came to light. The system when calculating random events uses a number line, which is the same for every run provided the initial start seed is the same. Therefore the random variation that occurs in the base model, can be seen as the same with the varied models. That is the combinations of engine inputs and work time variations will remain the same.

In getting the most from the simulation model the team met and came up with a series of suggestions that were to be tried on the model. These suggestions were given time scales and priorities in order of their modelling difficulty. An information notice / questionnaire was also produced and distributed throughout the IBU company members giving them information about the simulation project and asking for any ideas that could be used for simulation exercises.

Several company members became very interested in the application of the simulation model and various demonstrations were given to groups from the shop floor. The modeller was based on the shop floor with open access to everyone who wanted to discuss the project.

4.3.1 *'What- if '* Modelling Variations

A series of 'what- if' variants were produced for investigation by the simulation team. All of the work to be done was based around the need to reduce the TAT time of engines / modules through the IBU as a whole.

The initial set of variants were produced:

* The removal of an electro-static booth from crack detect coupled with a 75% reduction in cardwork.
* Implementation of a RB211 04 Module KANBAN in the strip shop.
* Implementation of a RB211 04 / 05 Module KANBAN in the strip shop.
* The movement of one nightshift strip shop worker to 04 / 05 inspection.
* The training of the stripshop nightshift to be able to work Olympus engines.
* Increase of the afternoon shift in the DVB.
* Implementation of a single shift in DVB.

This list shows the major investigations carried out on the model. These iterations were carried out with the advice of the supervisors of the areas. This was to allow the supervisor to see how the system would run if the changes were actually made. Some of these iterations took a great deal of time and substantial change to the model. Detailed results of all these investigations, coupled with comments as to how the system would react in practice are given in Appendix 7. An example of a result is shown in Figure 14.

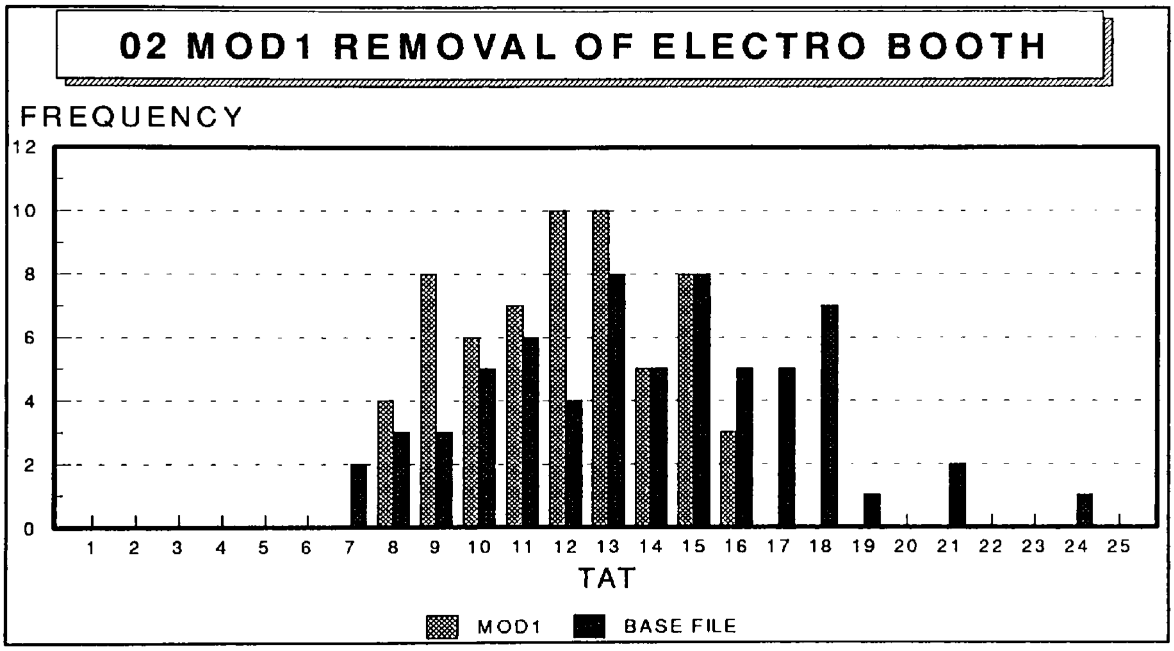

Figure 14. Example of a Resulting Graph

CHAPTER 5 RESULTS

5.1 Introduction

To examine the results of the simulation runs, all the what - if results were compared against the base model. This was to examine the number of engines / modules passing through the system. The next stage was to compare the TAT distributions against each other. Another feature built in to the system was the use of a percentage change chart. This showed an overall change with one system against another. Listed out were the changes for each module / engine type, giving a +/- variation of TAT against the base model. As a general guide anything within +/- 5% was ignored as this was felt to be insignificant, and when applied to the real world system would be taken out with the variation allowed for the number of hours to do the job. The percentage changes were then averaged to give an overall figure. The results were then discussed with the simulation team.

The calculation of the overall percentage change figures used a formula which calculated an overall figure for the models TAT. This was based on the number of engines passing through being multiplied by the TAT. This was done for all the modules / engines in the base model. The same calculation was then applied to all the variations that were carried out. The figure was re-calculated for comparison against the base model where a percentage difference could be calculated. It must be stressed that this was not the only figure used to verify the changes made, but was used in conjunction with the distributions plotted.

5.2 Modelling the Removal of the Electro- Static Booth from Crack Detect coupled with a 75% Reduction in Cardwork

The aim of this investigation was to measure what the effect of removing one of the electro- static booths, coupled with a large reduction in cardwork, would have on the TAT of engines and modules passing through the system.

Cardwork represents items that have been repaired and need to be re-inspected in the crack detection line and in the detail inspection area. This causes conflict as to allocation of labour as cardwork is needed for engines that are already in work and need to be built to meet the TAT of the other business units. But this affects the TAT of IBU.

Assumptions:

i) All cardwork will be removed from the electro-static line

ii) There will be a 50% reduction in cardwork down the backline - this will be kept in the repair section and done in the electro-static booth.

Results:

Figure 15. shows an example of the resulting TAT distribution for the RB211 01 Module. All the resulting TAT distributions are given in appendix 7.1.

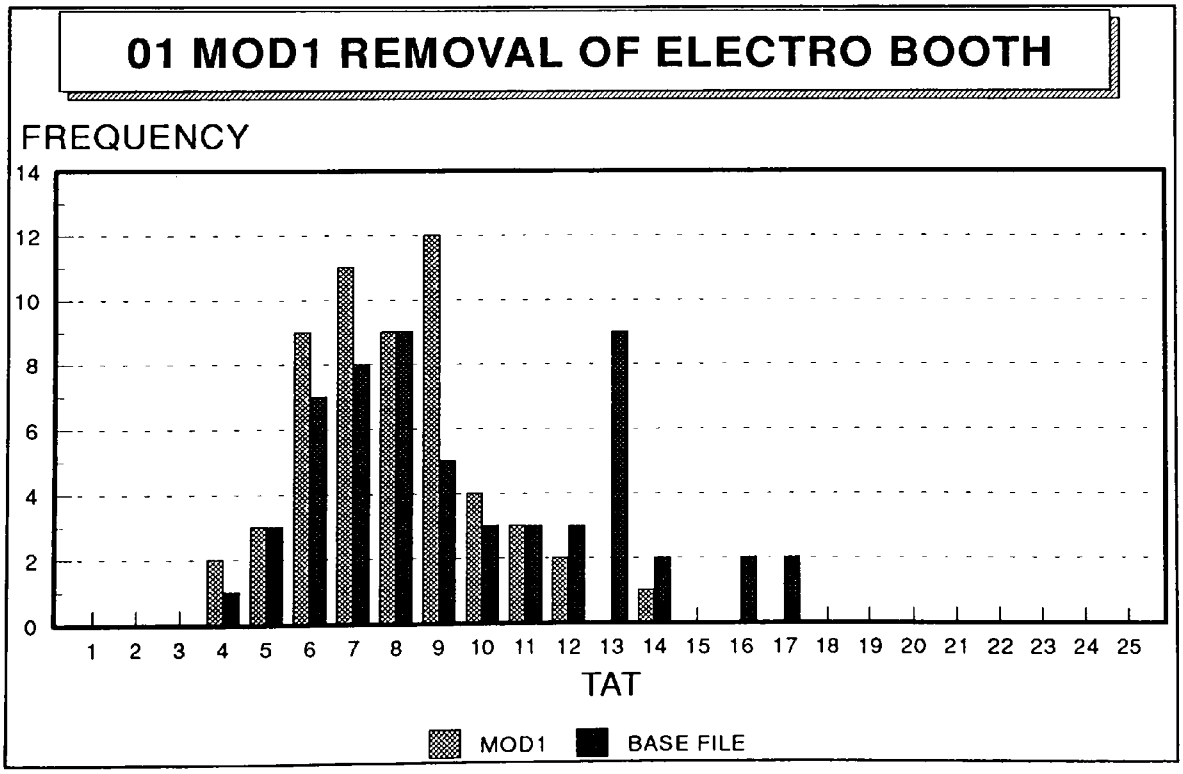

Figure 15. Example of Results for the Removal of the Electro-Static Booth

These distributions show the plot of the base model and the modified model. The overall TAT's were analysed against each other and the percentage changes worked out.

Table 4. Percentage Changes for Modelling the Removal of the Electro- Static Booth from the Crack Detection Line and Subsequent Reduction in Cardwork compared to the Base Model.

ALL		% Change
Engine	JT9	1.2
	JT8	-10.1
	OLY	2.2
RB211	O1	-16.7
	O2	-13.6
	O3	-13
	O4	-10.2
	O5	-8.4
	O6	-31
	AVERAGE	-11.1

As can be seen by Table 4. the changes virtually all show a reduction in TAT time for all engines and modules. Negative figures mean a decrease in TAT.

Recommendations:

The electro-static booth is removed to the repair section, with the associated reduction in the amount of cardwork passing through the crack detection section of the bay.

5.3 Implementation of an 04 KANBAN in the Strip Shop

The aim of this investigation was to examine what would happen to the TAT if the scheduling rules for the stripshop were to changed to make sure there was always a RB211- 04 module in work. The forecast shows that there will be a significant increase in 04 work, particularly RB211 G&H work as these engines are coming to the end of their allowable hours and many will need refurbishment.

Assumptions:

There will always be an 04 module awaiting strip, which will only be put into work when the previous 04 module is released from the stripshop. The 04 modules will always be worked, i.e. there should never be an 04 waiting for work.

Results:

All the resulting TAT distributions are given in appendix 7.2. Figure 16 shows an example of the results generated. These distributions show the plot of the base model and the modified model. The overall TAT's were analysed against each other and the percentage changes worked out.

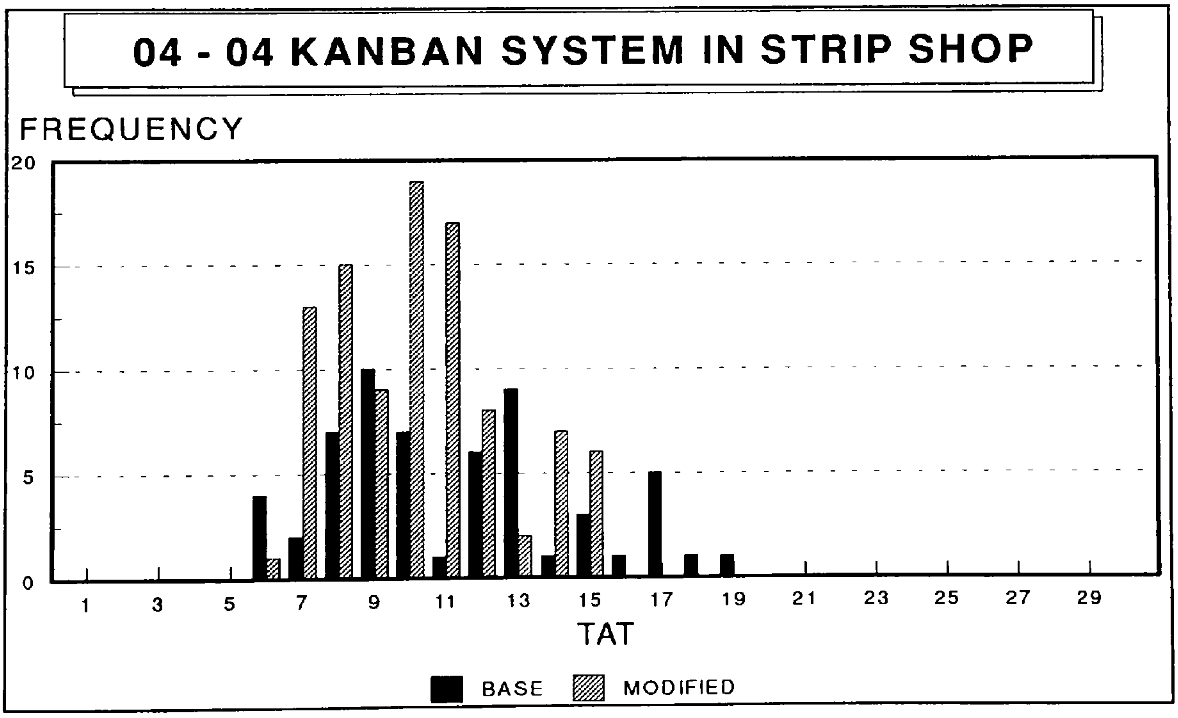

Figure 16. Example of Results for the Implementation of an RB211 04 Module KANBAN in the Stripshop

Table 5 Percentage Changes for the Modelling of the Implementation of an 04 KANBAN Scheduling System in the Stripshop Compared to the Base Model.

		% Change
Engine	JT9	-6.05
	JT8	-0.5
	OLY	-3.73
RB211	O1	3.67
	O2	-7.7
	O3	3
	O4	-9
	O5	-7
	O6	3
	AVERAGE	-2.6

Table 5 shows the changes that have taken place in the percentage utilisation figures of the manpower in the IBU. There is a very small change.

The resulting overall change shows there is very little change in the TAT of all the engines / modules. But what is significant is the increase in the number of 04 modules put through the IBU. There is a significant increase in the number of modules put through the system, as would be expected with the scheduling rules being changed, to allow the 04's to be continuously worked.

Table 6 shows the simulation results generated from this model in terms of resource utilisation of all the areas. The MAND1 to MANDD representing the stripshop shifts; CLEAN representing the cleaning bay; CRACK representing crack detect; and DVB representing the detail view bay. The 'Base' figure being the figures generated from the base model, with the figures from 'What- if' representing the changed model in terms of the introduction of the KANBAN scheduling system.

Table 6 Percentage Changes in Manpower Utilisation for the Modelling of an 04 KANBAN System in the Stripshop Compared to the Base Model.

	Base Model	What- if	% Change
MAND1	84	89	5
MAND2	87	91	4
MAND3	76	90	14
MANDD	72	82	10
CLEAN	17	18	1
CRACK	63	55	-8
DVB	76	79	3

Of significant interest was the use of the resource utilisation figures that the model automatically generates. These figures allow analysis of how often a resource is in work. Overall there were rises for all the utilisation figures, meaning that the use of a more controlled scheduling technique actually increased the efficiency of the business unit as a whole.

The KANBAN system does not really effect the cleaning bay, benefits crack detection, with an actual reduction in queuing, but causes queuing in the detail view bay. This is to be expected due to the increase in the number of modules passing through the system. Dennis Towill (1993) suggests that 'KANBAN controls necessitates that shop floor loading is more or less constant. In other words, extreme variations in capacity will cause the system to break down.'

The reduction in TAT for engines can be counted in the variation allowance. The general downward trend of all these figures means there has to be some benefit to TAT by introducing the KANBAN. Two reasons can be cited for the introduction of these KANBANS in reducing TAT:

i) It removes some of the variation in the system, with an 04 being inputted when one leaves the system, and 04's being continued to be worked at all times there is far more control over how long it takes to work the actual module in the strip shop.

ii) The KANBAN prevents 04's entering the system in a shorter time scale and hence queuing in the shop, where the TAT is measured. Though the queuing time for these modules still occurs they will queue outside the IBU and not add to the work in progress figure.

Recommendations:

i) That 04 modules are only brought into the shop only when there is one completed or that only one 04 is in work in the stripshop at any one time. This will relieve the pressure on the subsequent sections. Obviously different arrangements will have to be taken into consideration when dealing with the various workscopes that can be called on the modules. e.g. the repair workscope on an 04 which means it is only split into two sections, neither of which having any cleaning or crack detection requirement.

5.4 Implementation of an 04 and 05 KANBAN in the Strip Shop

The aim of this investigation was to look at the affects of introducing a KANBAN scheduling system on 04 and 05 modules in the strip shop. This would effectively control the inputs, the aim being that this would allow one of each of these modules to be in work at any one particular time.

Assumptions:

i) The modules will only be inputted as one leaves the stripshop.

ii) These modules have priority in the strip shop, that is they will always be worked first in the shop.

iii) There will always be a module waiting outside to satisfy the KANBAN.

Results:

Resulting TAT changes are shown in Appendix 8.3. An example is given by Figure 17. There is a significant rise in the overall TAT figures generated by the modified model. There are small increases in the engine TAT's but much more significant a greater increase in the RB211 modules TAT. This can be somewhat offset by the increase in the amount of work passing through the system. There is a significant increase in the number of 04 and 05 modules passing through the IBU. When this number of 04 modules is compared against the number of 04s passing through the system with just an 04 KANBAN, there is a decrease.

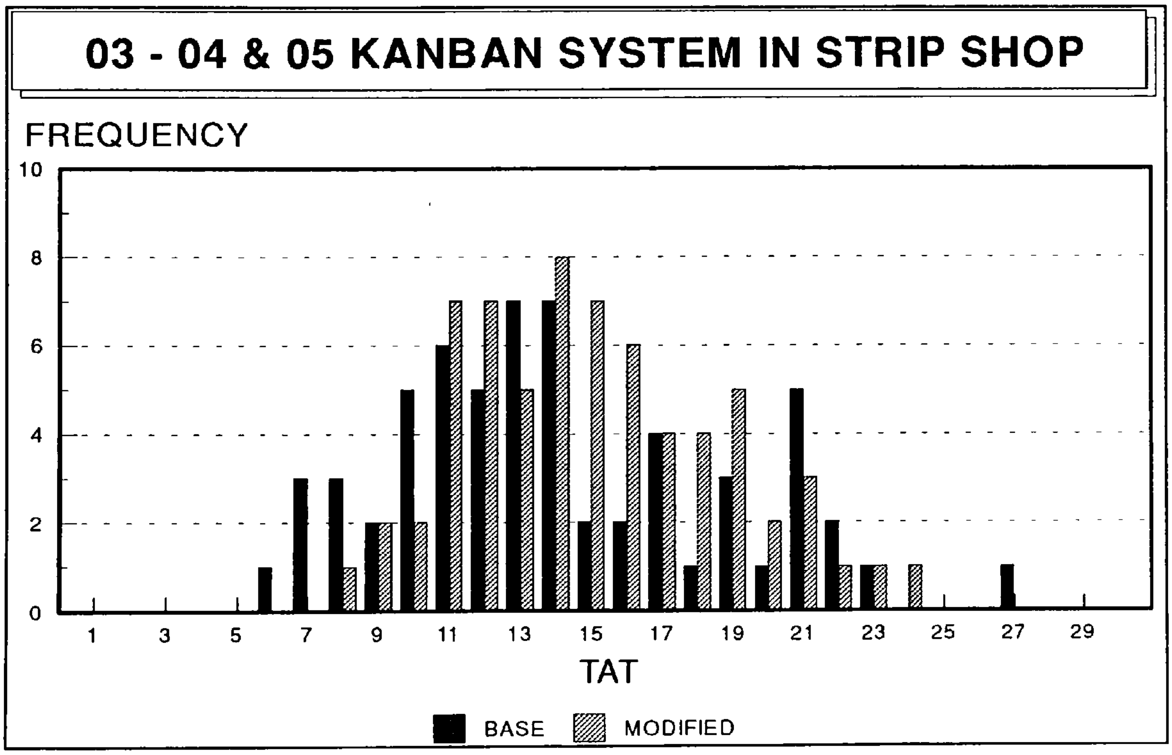

Figure 17. Example of the Results from the Implementation of an RB211 04 and 05 Module KANBAN in the Stripshop

Table 7. Percentage Changes for the Modelling of the Implementation of an 04 and 05 KANBAN Scheduling System in the Stripshop Compared to the Base Model.

		% Change
Engine	JT9	-0.2
	JT8	4.78
	OLY	3.69
RB211	O1	29
	O2	6.85
	O3	19.8
	O4	12
	O5	-2.4
	O6	22.2
	AVERAGE	10

Table 7 shows the percentage change in TAT figures for the model run. The chart below giving percentage changes in the percentage utilisation figures.

Table 8. Percentage Changes in Manpower Utilisation for the Modelling of an 04 and 05 KANBAN System in the Stripshop Compared to the Base Model.

	BASE	MOD5EX2	%CHANGE
MAND1	84	92	8
MAND2	87	94	7
MAND3	76	94	18
MANDD	72	90	18
CLEAN	17	19	2
CRACK	63	62	-1
DVB	76	89	13

Table 8. gives the details of the resource utilisation figures generated from the base model and running the KANBAN system, complete with percentage change figures.

Discussion:

The idea of running two KANBANS together for 04's and 05's is feasible, but as the assumptions state there will always be a module in work this will effectively tie up a great deal for the workforce. This is seen in the overall change in the TAT figures which increases dramatically, particularly for RB211 modules not in the KANBAN system. The only offset with this increase in TAT is the increase in the number of 04 and 05 modules put through the system.

What is also seen is an increase in the resource utilisation figures given in Table 8. There are quite dramatic changes in these figures, with the utilisation of the system increasing. The system has a higher yield, with more modules being produced, but with an increase in TAT times. This was seen from the investigation conducted on just the 04 KANBAN. Various conclusions can be drawn from this. The first one is the link that can be drawn from the amount of work in the system and the TAT. Basically the lower the WIP, the lower the TAT. This theory was also proved through the use of a synchronous flow / lean manufacturing exercise. This is discussed in chapter 5.

Recommendations:

i) There is an increase in throughput, but also an increase in TAT. The aim of the investigation is to reduce TAT. This type of KANBAN should only be implemented if the workload requires it. Perhaps if some system was developed so as to KANBAN all the engines / module types and therefore control all the WIP, this would be a better system to introduce. To be able to do this effectively the capacities and relationships of all the areas would need to be understood in a far more detailed nature than the model created allows.

5.5 The Movement of one Nightshift Stripshop Worker to 04 / 05 Inspection

The aim of this investigation was to investigate the affect of moving one strip shop nightshift worker to the detail view bay for detail inspection on 04 and 05 modules.

This represents a facility that is available at the moment but not utilised very often. The assumptions that are made mean that the workers first priority is to strip 04 and 05 modules, followed by detail inspection. The aim of this flexibility is to allow further help on the longer modules in the detail view bay, which can utilise one man for up to five days.

Assumptions:

i) The workers first priority is stripping of 04 and 05 modules if there are any available, this is followed by work to be done in the detail view bay.

ii) This man only works on 04 and 05 modules in both shops.

iii) If the man has started in one shop, then he will continue to work in that shop for the rest of the shift. He will not be working in the detail view bay, and suddenly move to the strip shop when a module is inputted.

Results:

The run of the simulation with these modifications resulted in results indicating very little change. If anything there was a slight decrease in JT9, JT8, Olympus and 05 engine / module TAT reductions. All the resulting distributions are given in appendix 7.4. Figure 18. gives an example of the results plotted. Here the base model results are plotted against the results given by the variation in the model.

Discussion:

Though this represents only a small change in the running of the IBU there are some interesting points which are of note. Due to the assumption being made that the man's priority is the strip shop, his original work station, there is very little change in the performance utilisation figures of the nightshift, an increase being seen of only 2%. This figure represents the time the man is away working in the DVB.

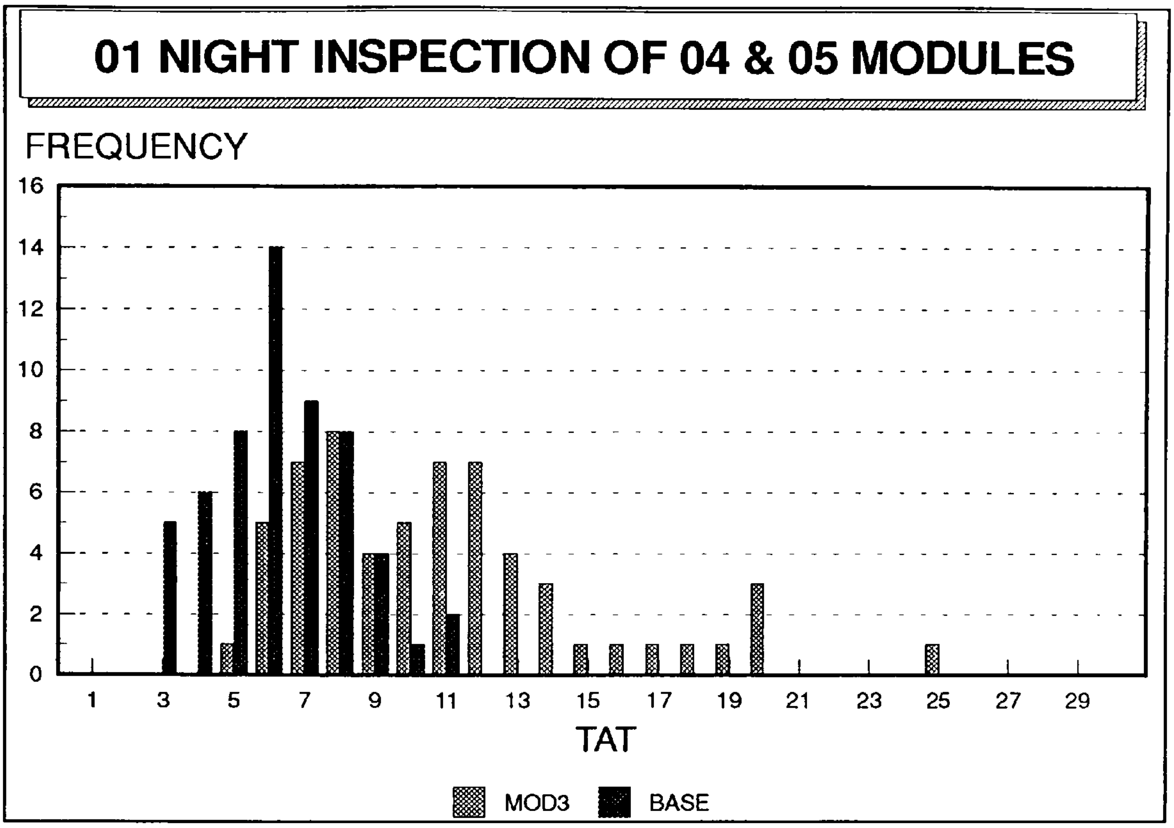

Figure 18. Example of the Results of Moving One Nightshift Stripshop Worker to 04/05 Module Inspection

The man added to the detail view bay will help in clearing the longer modules such as the 04 and 05. He will aid in starting and finishing modules that come into the DVB, increasing the capacity of the shop for 04 and 05 modules, and thus releasing manpower to work on other modules, hence the slight decrease in TAT for all the engines.

This increased flexibility allows 04 and 05 modules to be worked on a three shift basis if required. This is dependent upon the right skills being available. This ability should aid in decreasing the TAT for the 04 and the 05 modules.

The ability to work the longer module in the detail view bay on a three shift system is very useful. But it must be remembered that moving a man into the detail inspection bay increases the capacity there, but will decrease the capacity of a different area, in this case the strip shop. Thus this flexibility is very useful but must be used with caution. Moving all the capacity to the ends of the system will either cause a blockage if the capacity in strip is increased, or a famine of work if all the capacity is moved to the detail view bay, reducing the capacity in the strip shop.

Recommendations:

i) Steps should be taken to increase the flexibility of the strip shop nightshift as regards moving men between strip and detail inspection. This would mean instigating a training program for the nightshift on the longer inspection bay modules e.g. the JT9 B module and the Olympus 061 module.

ii) Any movement of people between the various shops must be viewed with caution as stated in the discussion.

5.6 The Stripshop Nightshift to be trained on the Olympus Engine

At present the nightshift in the strip shop are unable to work the Olympus engine due to their lack of training. This simulation was to see the benefits of embarking on a comprehensive training program to allow the nightshift the ability to work the Olympus engine.

Assumptions:

i) Nightshift has the ability to work all engine types.

ii) Work is still done on a first in - first out basis.

Results:

All the results of this run are shown in Appendix 8.5, and were as expected. Figure 19. shows an example of the results generated. There would be a decrease in TAT on the Olympus engine due to the fact it would now be worked on three shifts rather than the previous two shifts. The trade off effect is that the other engines / modules in the system would probably see a slight increase in TAT. This is due to manpower working on the Olympus, when previously they would have been working on other engine / module types.

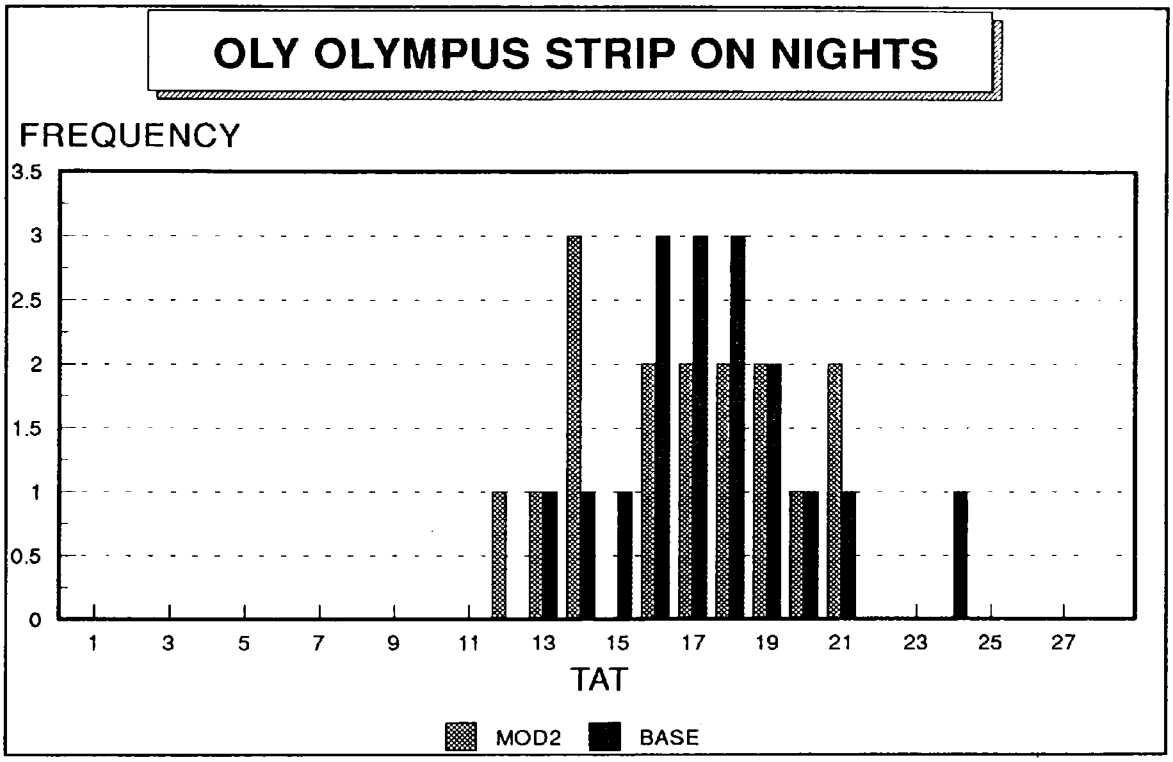

Figure 19. Example of the Results Generated from Training Stripshop Nightshift to work on the Olympus Engine

In the case of the JT8 engine, the TAT figures did increase, but the variation decreased. This can be put down to the first in - first out (FIFO) system which is operating. This means at present that an Olympus is first in the queue, and is in-work when the nightshift come on, but as they are not trained on working it, they 'leap frog' it and go on to the next engine, a JT8, when the next day shift come in, they work the Olympus as this was 'first in,' and only when that is finished do they continue work on the JT8.

Discussion:

Though the changes seen in the TAT figures are quite small, an average increase of 3%, it is necessary to see the results from a wider angle. To be able to work all engines on the nightshift is a necessity to achieve the total flexibility that is required in the drive for reduced TAT. There may be times when the only work available is an Olympus engine, and this is when the training benefits will be reaped.

Recommendations:

i) A training program is started for the nightshift on the Olympus engines.

ii) This flexibility must be built into a more organised scheduling / KANBAN system taking into account capacities / capabilities.

5.7 The Increase of the Afternoon shift in the Detail View Bay

From observing the animation of the model being run, it was noticed that there was always queuing occurring before modules entered the Detail View Bay. This was felt to be a major factor of the total TAT for the IBU. One of the ways of possibly speeding up the throughput was to change the existing shift pattern and increase the number of people on the afternoon (p.m.) shift. This would effectively decrease the number of people on the day shift.

Assumptions:

i) The day shift is reduced by 5 men

ii) The afternoon (p.m.) shift is increased by 5 men

iii) The rest of the IBU works as per existing shift (modified double days)

Results:

Figure 20. shows an example result of the investigating compared to the base model. All the resulting graphs are shown in Appendix 8.6. Overall there were significant increases in TAT for all engine / module types. These were particularly high for the

JT9 and all the RB211 modules, all of these giving an increase of over 20%. Table 9 shows the percentage increases.

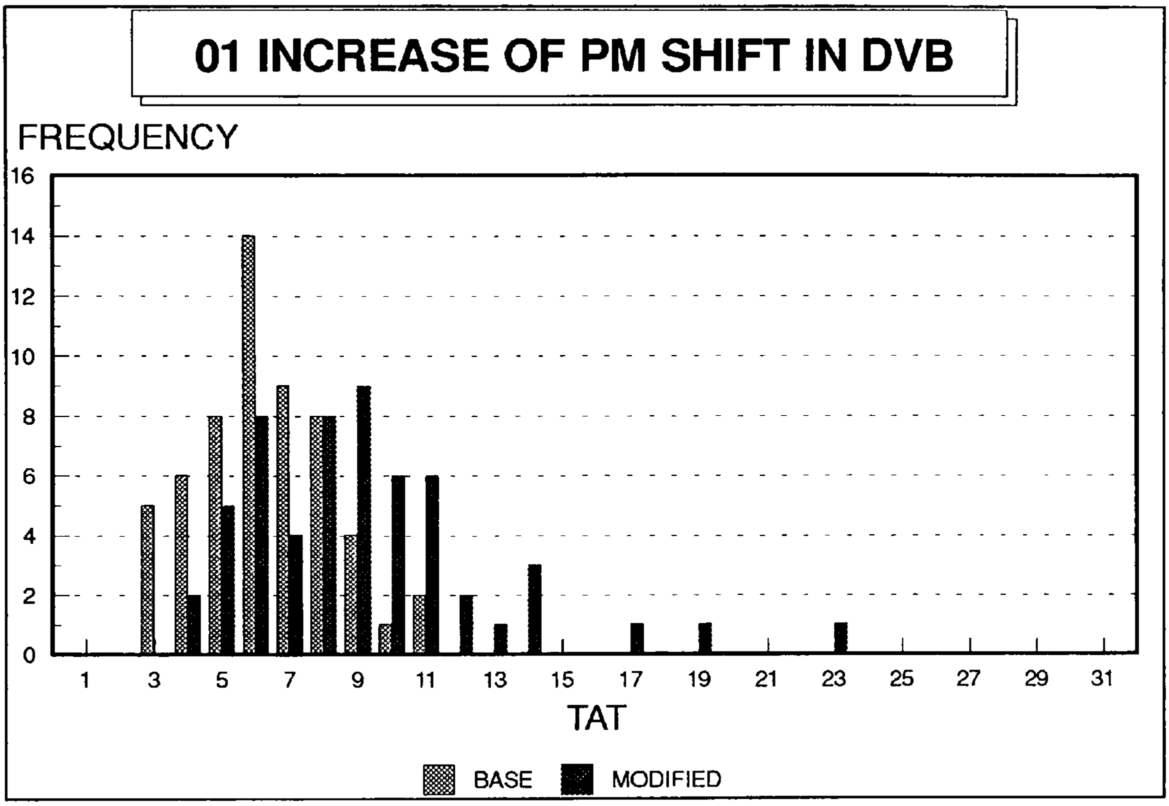

Figure 20. Example of the Results Generated by Examining the Increase of the Afternoon Shift in the DVB

Discussion:

To have an increase in TAT of 27.87%, there would have to be something significantly different with the system. When examining the figures generated by the model for percentage utilisation of the locations it was noted that there was a very large increase in the time that the modules spent:

1) queuing to go into work in the DVB (+15%)

2) actually in work in the DVB (+12%)

It must be remembered that training is also linked into this investigation. If all the men are able to inspect all modules then there would be a considerable improvement in

TAT. But this is not a pratical situation. In general most inspectors are trained on two major modules (RB211- 04,05; JT9 - B,C,D; Olympus 061), and then generally three or four smaller modules (RB211 - 01,02,03; JT9 - A,H; Olympus 01,02,03).

Table 9. Percentage Change for the Increase of the PM Shift in the Detail View Bay Compared to the Base Model.

		% Change
Engine	JT9	39
	JT8	6.5
	OLY	8.3
RB211	O1	44
	O2	25
	O3	25
	O4	30
	O5	22
	O6	51
	AVERAGE	27.87

It was decided by the simulation team to look further into the effect of modifying the shifts in the DVB to improve the throughput.

5.8 The Implementation of a Single Shift in the Detail View Bay

The aim of this model is to view the changes that would be made if the DVB was placed on a single shift system just covering a day shift with reduced numbers available for weekend work. This is following on from the work done on the previous model looking at the increase in the PM shift in the DVB.

Assumptions:

i) All men in the DVB work day shift.

ii) Numbers are reduced for shift coverage at the weekend, 5 men on days.

iii) The rest of the IBU works as per modified double day shift.

Results:

The full set of comparison graphs are given in appendix 8.7. Figure 21. gives an example of the graphs generated. There are increases on the 01 and the 06 modules. Both of these having increases of over 15%. The rest of the engines / modules have no significant changes. The overall average increases by 3.67%. Table 10 shows the overall percentage increase is given below:

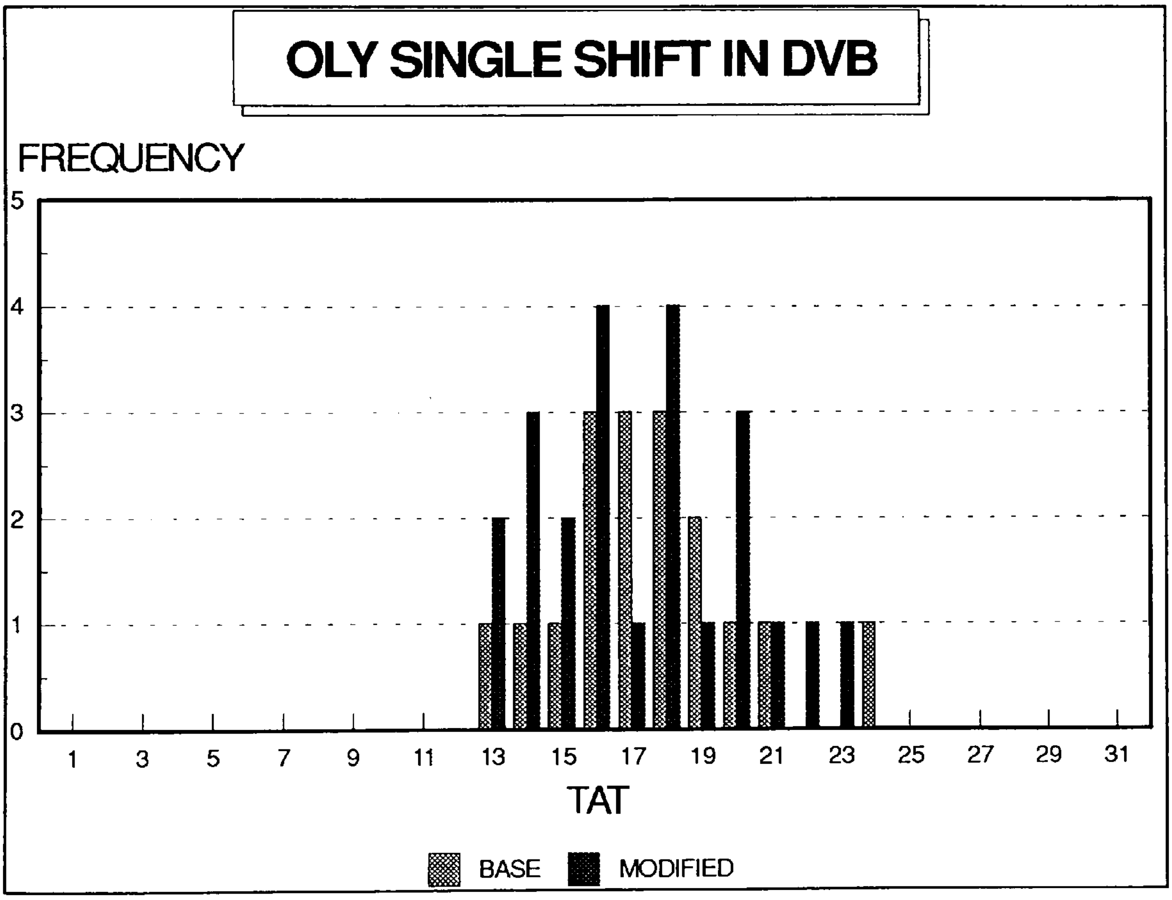

Figure 21. Example of the Results Generated by Investigating the Implementation of a Single Shift in the DVB

Discussion

The present working practice in the DVB means that one man picks up one module, and works on that until it is finished. In this case the shift is really immaterial, what is more important is the way the engines / modules are scheduled in, to prevent swamping the trained men with the same type of module. If any significant changes are to be made to improve the system in the DVB, it will rest around the need to change the working practices.

Table 10. Percentage Changes in the Modification of the Shift System in the DVB to Introduce a Single Day Shift, with Reduced Weekend Coverage.

		% Change
Engine	JT9	7
	JT8	-2
	OLY	0
RB211	O1	16
	O2	2
	O3	-7
	O4	1
	O5	-2
	O6	18
	AVERAGE	3.67

A discussion was held with the simulation team and the supervisors and workforce of the area as to whether it would be possible to split the large modules into smaller 'day-long' pieces of work i.e. if it takes one man five days to inspect an 05 module, it will take five men one day. A separate model was constructed to look at the DVB and its requirements.

5.9 The Separate DVB Model

The aim of this model was to increase the throughput and reduce the TAT in the DVB, looking specifically at the working practices, shift patterns, and training requirements. The greatest TAT reductions in the IBU being seen to be made in the DVB. The aim of the simulation was to look at the difference in TAT that a change in working practices would bring.

The reason for a separate model was to allow quick runs and quick analysis of the results without having to examine the whole of the IBU simulation model. The runs would also be significantly quicker due to the size of the model, and also more detail could be put into the analysis of the system, as some of the ProModel reporting features proved ineffective when dealing with a large model. The animation could also be examined more effectively to see any significant variations and to understand the workings of the system.

5.10 Use of Animation

While the simulation model was being run, various points were noted about the model. Due to the construction of the model it was necessary to place before each section a queue, or waiting area. This is where the modules waited if there was no capacity available in the following section. This proved a very useful tool as later analysis allowed for the utilisation of these queues to be examined. This gave information as to how often the capacity of the following area was full, or the men / machines required were not available for work.

The major area for queuing was the holding area placed before the detail view bay. The very nature of this job is that it is manpower and skills dependent. Also if one of the larger modules comes to the DVB it can use a single man for over a week. Various scenarios were tried, including modifying the shifts to a single shift, or an increased afternoon shift. Neither of these had a significant impact upon the TAT figures that were being collected. What became evident was a change in the working practices was required. This was further highlighted by the KAIZEN exercise carried out in the detail view bay (see chapter 6.3).

CHAPTER 6 ACTIONS TO BE TAKEN !

6.1 Introduction

This chapter deals with actions that need to be carried out to achieve a reduction in TAT in the IBU following the investigative work carried out with the simulation model.

6.2 The Movement of a Crack Detection Booth

Prior to the simulation model being built and tested, a great deal of work had gone into looking at ways of reducing the amount of cardwork that came down to the input business unit. With the creation of the simulation model it was possible to measure the effects that cardwork had on TAT, and what effects reducing the amount of cardwork passing through the IBU would have on the overall TAT.

6.3 KAIZEN

A demonstration KAIZEN (Lean Production Systems / KAIZEN 1991) project was run in the detail view bay, to demonstrate the way such projects should be carried out. This was run by a G.E. specialist in manufacturing systems. The aim of the project was to look at reducing waste in the shop. Waste is interpreted as non-value adding activities. The actual project involved spending time on the shop floor looking at the way in which detail inspection was carried out. This involved timing all the activities that took the company member away from his designated job. Examples of which are: movement of jobs; paperwork queries; queries from sub-assembly; and the location of manuals. Also included were jobs which did not need the required skill level of an inspector, examples of this included the etching of components. This is done on British Airways Extended Range Operations (EROPS) engines. At present this operation only effects RB211 524 G+H engines used on the Boeing 767.

Another part of the KAIZEN exercise was the use of a paper simulation model looking at lean production techniques. This involved examining the customer requirements and then balancing all the work processes in the system to match this. The problem was trying to apply the philosophy to the business of overhaul and repair. Of major concern was the fact that each job varies in the length of time taken. The variation can be as much as a 300%. Warness and Gooch (1994) recognise this problem in their work on introducing synchronous flow techniques 'one engine may require 2000 hours of labour and the next may demand just 200. Balancing one operation against the next within this erratic scope is virtually impossible.'

One of the key concepts of this lean production systems is the fact that a reduced amount of work in progress (WIP) will lead to reduced TAT. A large amount of the theory discussed was suitable for a manufacturing environment but not for a repair environment. It is the inability to standardise the variation that causes the problems in reducing TAT.

6.4 The Existing System

The existing working practice in the DVB is that one man works on a job until he has completed it. In some cases this could take as much as five days for an RB211 05 module. For the JT9 B module, the work is split into two, there being a natural split of rotors and static's.

6.5 Bay in a Day

The idea of splitting modules into one day lumps originated from one of the discussion points from the simulation model, as being the only way to make a drastic reduction in TAT through the use of an operational change. The theory stating that given the right capabilities (training) an engine could be inspected in a day.

6.6 Paper Justification / Synchronous Flow

Figure 22. shows the basic concept of the bay in a day project coupled with some idea of the reductions in TAT that can be seen with its implementation. The diagram given is for a small module that would normally take 12 hours. Obviously the TAT reduction with larger modules is more dramatic. The biggest example here being the RB211 05 module where, with a team of five men, the TAT can be reduced from 40 hours (5 shifts) to 8 hours (1 shift).

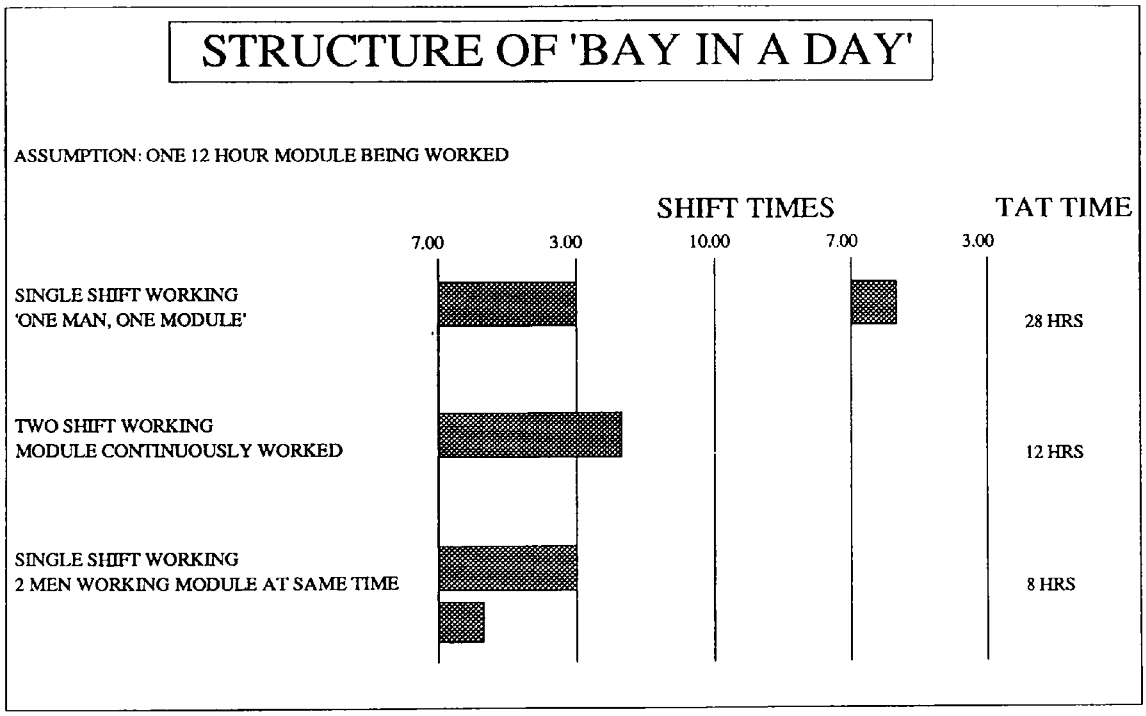

Figure 22. Structure of 'Bay in a Day'

6.6.1 Implementation Plan

To change the working practice of the detail view bay to allow for the implementation of the bay in a day concept various changes had to be made. To prove that the theory worked in practice a 'demonstration / practice' module was run. The module chosen for the demonstration run was a RB211 05 module. Preparation for this included:

i) Changing the engine / module manuals to produce a separate manual for each separate 'mini-module' e.g. on the 05 there would be five manuals, each consisting of the required Illustrated Parts Catalogue (IPC), Repair Section, and Inspection. Therefore each team member would have a separate manual to work to.

ii) The paperwork was reviewed to mark on the inspection sheets critical items and routine replacements. Critical items being the parts of the module which have the longest repair time and require the longest inspection. Routine replacements are parts which are replaced at every shop visit. The aim here was to reduce the inspectors time by setting up a system to automatically call out all the parts that are needed every time.

iii) The production of a layout book of photographs showed the position of each nut and bolt on the cube / pallet. This was to reduce the amount of time spent looking for lost parts and searching for parts on the cube. This was implemented at the strip shop, and copies of the book made for both cleaning and crack detect. This was produced in conjunction with all the sections of the detail view bay, and in the case of the 05 led to two cubes being used, one containing items for crack detection, the other non-crack detected items.

iv) Making sure that the module had been measured using the Co-ordinate Measuring Machine (CMM) before being passed to inspection in the detail view bay.

v) Making sure all the items on the RB211 G+H modules had been etched. This is a requirement of the customer to differentiate the parts from non- extended range operation (EROPS) engines.

vi) Placing all the cubes and pallets in position in the DVB to allow the team to commence work on them as soon as possible, and not to have to worry about finding all the parts of the module and then having to pull the parts of the module into place.

The demonstration module, 05/8410, was inputted into the detail view bay on the 16th July 1993, and with a team of five company members was completed in the required time period of one day.

Another two 05 modules were run as demonstration modules just to prove that the system did work. After these three modules had been completed using the new working practice a team debrief was held to discuss the bay in a day concept and whether it was viable to introduce this concept onto all the modules being worked in the detail view bay.

6.6.2 RB211 Implementation

The conclusions drawn from the team were that the system worked extremely well and could be implemented on all types of work passing through the detail view bay. The initial target was to introduce the concept on to all RB211 modules and then to progress the concept onto the other engine types.

The key to the bay in a day concept was the capacity of the detail view bay. Capacity in this sense is the number of trained inspectors available. For the teams to be formed it needed everyone available at the same time on the same shift. The present system of running both an afternoon and a weekend shift, significantly reduces the amount of men available on the day shift. Training is a key issue. Having a large number of men on a particular shift with the wrong training for the work available will lead to an extended TAT.

To implement the bay in a day project across all engine types the following recommendations were made:

i) All manuals be revised to the new system

ii) All paperwork be reviewed and updated

iii) Shift patterns be reviewed

iv) Training programme reviewed

v) Layout books (photographs) be produced for all modules

vi) Scheduling rules are adhered to (see chapter 5.6.3)

vii) Support services are made aware of requirements and time scales

viii) Modules must be complete, and laid out ready for an immediate start in the morning

6.6.3 Scheduling

This was identified as a major requirement for the 'Bay in a Day' project to succeed. This meant not only planning for when the module was going to arrive at the detail view bay, but also making sure there was a team available to inspect the module. Also to be taken into account was the planning of the work into the CMM room. This became very complex as the company members who inspected the RB211 modules also inspected the other engines that are worked on in the detail view bay. There was also the shift system to consider which again meant that some of the inspectors were not available on certain days, as they worked weekends.

Consideration had to be given to the move of RB211 Repair and Return module work from the Engine Business Unit to the IBU. These modules are left in a built up state to allow for a visual inspection with the minimum of stripping, to allow for the module to be replaced on the same engine that it was removed from. The target for strip to complete inspection was given as four days. These were included into the schedule and had priority over other work. This was because on finishing inspection they were placed directly into the build cycle.

The actual scheduling was done for the RB211 modules through the use of the program which was monitored on a daily basis. A planning board was installed in the detail view bay. This was used to identify which modules were to be worked on which day and who was to be in the team.

Another improvement to the scheduling process has been the introduction of a scheduling board into the crack detection area of the IBU. Modules are marked up when they are ready for crack detect, with all the different processes they require being marked against them.

6.6.4 Problem and Pitfalls

The major problem envisaged with introducing this system was in the scheduling of the engines / modules into the detail view bay. The bay in a day concept requires that there should only be one of each type of module being worked in the DVB at any one time. There were various controls introduced to make this rule applicable. The major one being the allowance of only one set of manuals for each RB211 module. The other control factor for this was the use of teams, allocating a module to a team to complete.

Also of concern was the inability at certain times to make a work team to 'pick up' on the engine module. The RB211 05 module requires a team of five men to work on it at the same time to produce it in a day. If only four men are available due to leave and sickness, the scheduler is faced with a very difficult situation - do we work it today knowing it will not finish in the specified time, or do we leave it till tomorrow when we might have a full team available to work on it. When this situation occurs the aim has been to try and still complete the module in a day using overtime where possible. If this is not possible and the workflow is reduced then the module has been worked over a two day period.

The worst situation occurs when there is an RB211 04 module planned in every day of the week, but are unable to make a full team and unable to complete it on overtime. Unfortunately the module has to be carried over to the following day. This leads to a knock on effect causing the all the modules planned that week to be produced one day later, and perhaps the final module being pushed out into the following week. In this case the problem is capacity. There are only a certain number of men available and a certain number of man-hours available. If both of these are exceeded in the weeks production plan then something is not going to produce. Again this is up to the scheduler to work out what is urgent and what can afford to be pushed back to the following week.

One must also remember that the detail view bay is not just dealing with RB211 modules. It also has to deal with a constant supply of engines, coming through in any order. If these have priority then men are dropped off the RB211 Bay in a Day project. When all the engines come under the guise of 'Bay in a Day' then the schedulers task should become easier being able to assign resources knowing that the engine / module will be complete in a day.

One of the greatest problems was the way in which the project introduction was perceived by the rest of the business. As with all new project introductions it was greeted with a great deal of scepticism, and as a result was blamed for anything that went wrong in the entire factory, from the inadequate supply of parts to the problem of missing paperwork. To combat this an awareness campaign was introduced using the companies newsletter, 'Fit for the 90's' briefing sessions, and a presentation given to the senior management group. As the new system of working has now been running for over six months a gradual understanding and acceptance of the new working method has come across. This is seen especially in the supply of British Airways RB211 G+H engine modules to the engine business unit, to cope with the ever increasing throughput. British Airways were concerned as to whether EMMS could handle the amount of work necessary to cope with the influx of RB211 524 G+H engines. Without the 'Bay in a Day' project, the input business unit would not be able to supply the modules required to the engine business unit, and hence to the customer.

6.6.5 Training Program

One of the major constraints identified was that of training. The original training program for the detail view bay had to be reviewed. The initial target for the amount of work to be produced in any one day was that of one engine and two RB211 modules.

A skills matrix was produced and recommendations made for people to be trained. The initial target being to have everyone trained on two major modules. These being identified as those modules which would take three days and over to complete by a single man. e.g. JT9 B,C,D; Olympus 061; RB211 02,04,05.

6.6.6 Results

The aim of introducing the 'Bay in a Day' project was to reduce the TAT figure for the detail view bay to a day for the inspection of RB211 modules. This has been successful as is shown by the graph in Figure 23. The TAT data that this is plotted from is given in Appendix 3.

The graph shows the monthly average TAT for all the RB211 modules, 01 to 06. As can be seen there is a downward trend for all the modules, except the 06 module (gearbox). This being an exception due to a change in the working practices involving the IBU having sole responsibility for the strip and inspection of the gearbox, compared to before where the gearbox was just stripped. i.e. more work. Table 11. shows the percentage change comparing April 1993 to April 1994. This gives a crude indication as to the level of success the project has had in reducing TAT. A negative figure indicates a reduction in TAT.

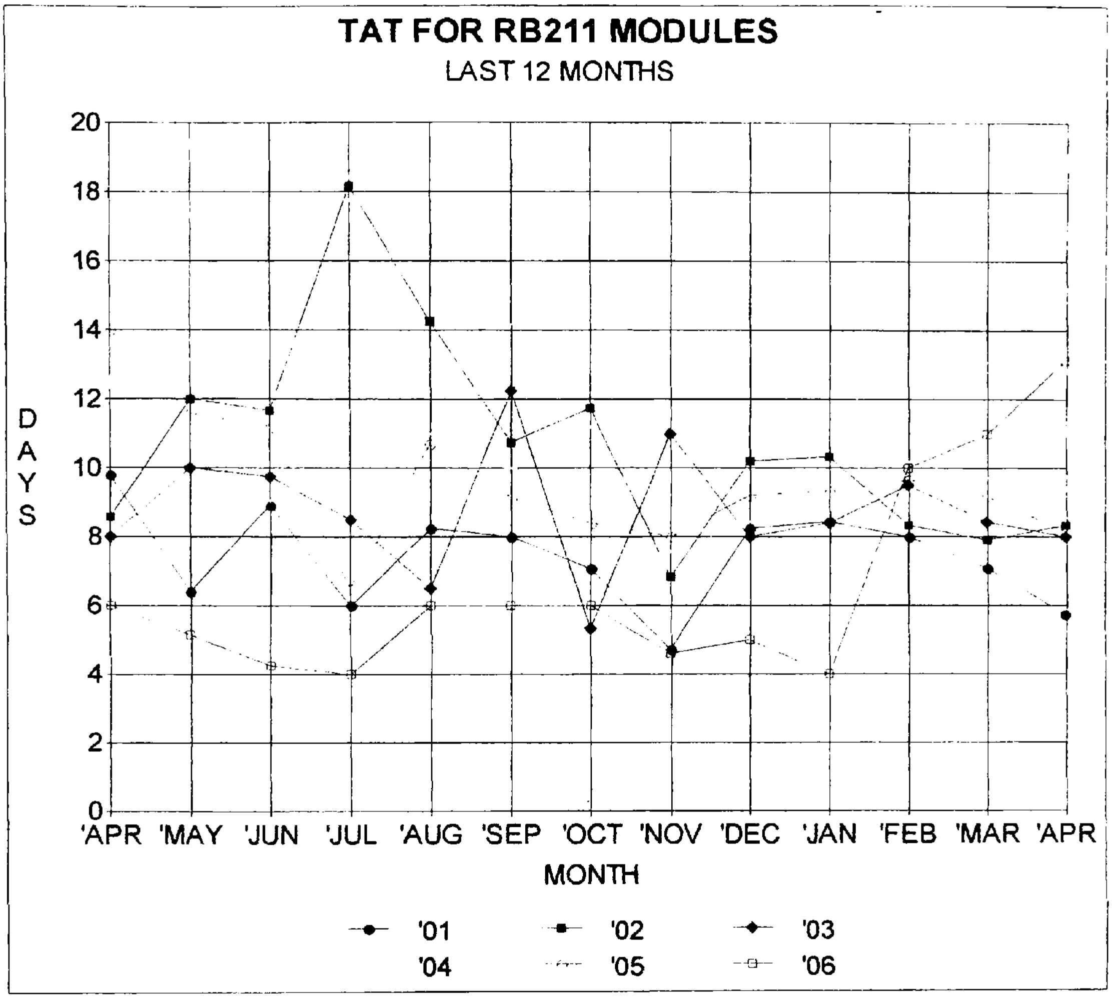

Figure 23. Average Monthly TAT for RB211 Modules April 1993 to April 1994

Table 11. Percentage Change for RB211 Modules April 93 Compared to April 94

Module	PERCENTAGE CHANGE
RB211 01	-41.4
RB211 02	-2.8
RB211 03	0
RB211 04	-37.6
RB211 05	-41.8
RB211 06	119

Coupled with the downward trend in TAT times there has been a significant reduction in variability of the TAT times. Since October 1993 the average TAT for all modules passing through the IBU has been between 8 and 10 days. This can also be seen by the value of $\overline{R}$ in the SPC charts shown by Figures 24 and 25, and by the SPC charts in Appendix 9.

The introduction of the ability to inspect modules within a day has made a significant contribution to the business. The BA RB211 G+H campaign being a prime example, where if EMMS had been unable to cope with the capacity of the work, BA would have taken the excess elsewhere e.g. Rolls Royce.

For this to be successful all the time there needs to be a great deal of time put into the actual planning of the work through the system, and then chasing up the actual placement of the module into the work area, coupled with the requirement to have the right paper work ,in the right place at the right time.

6.7 The Method Used for the Introduction and Analysis of SPC Charts

The work done in the actual construction and analysis of the control charts was developed by Shewhart in the 1920's. He defines control as 'A phenomenon will be said to be controlled when, through the use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in the future. Here it is understood that prediction within limits means that we can state, at least approximately, the probability that the observed phenomenon will fall within the given limits.'

The construction of the charts involved the plotting of all the TAT for each individual set of engines / modules and then the calculation of the variation of the ranges. A moving range of two was used for the analysis of the charts, due to the small sample size. Previous years have shown that there would normally be a maximum of 350 engines (all types) passing through the IBU each calendar year and each one of these will represent a value on the chart. It is the variation between two engines of the same type that is the critical measurement here hence the use of a moving range of two and

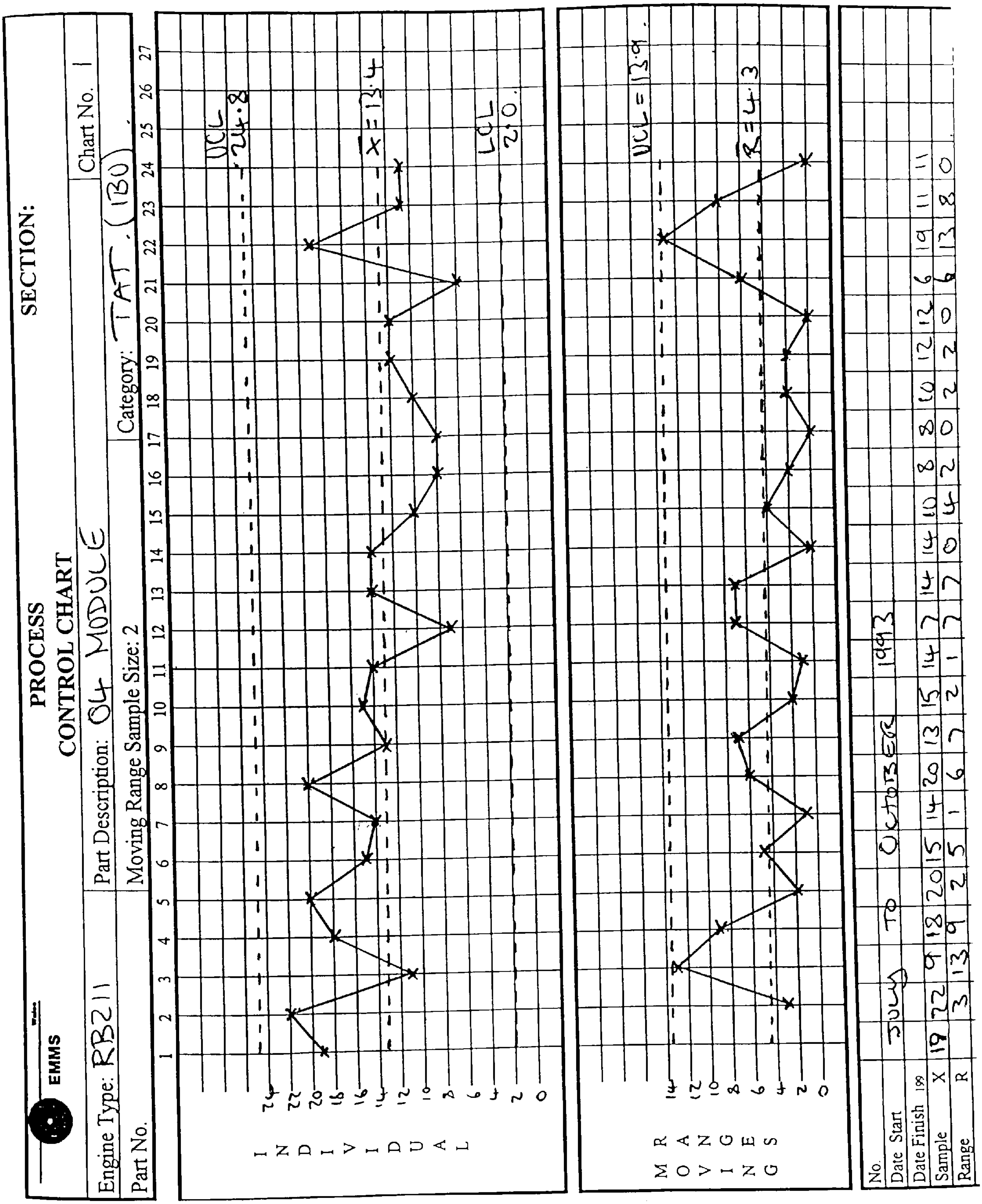

Figure 24 RB211 04 Module Process Control Chart 1

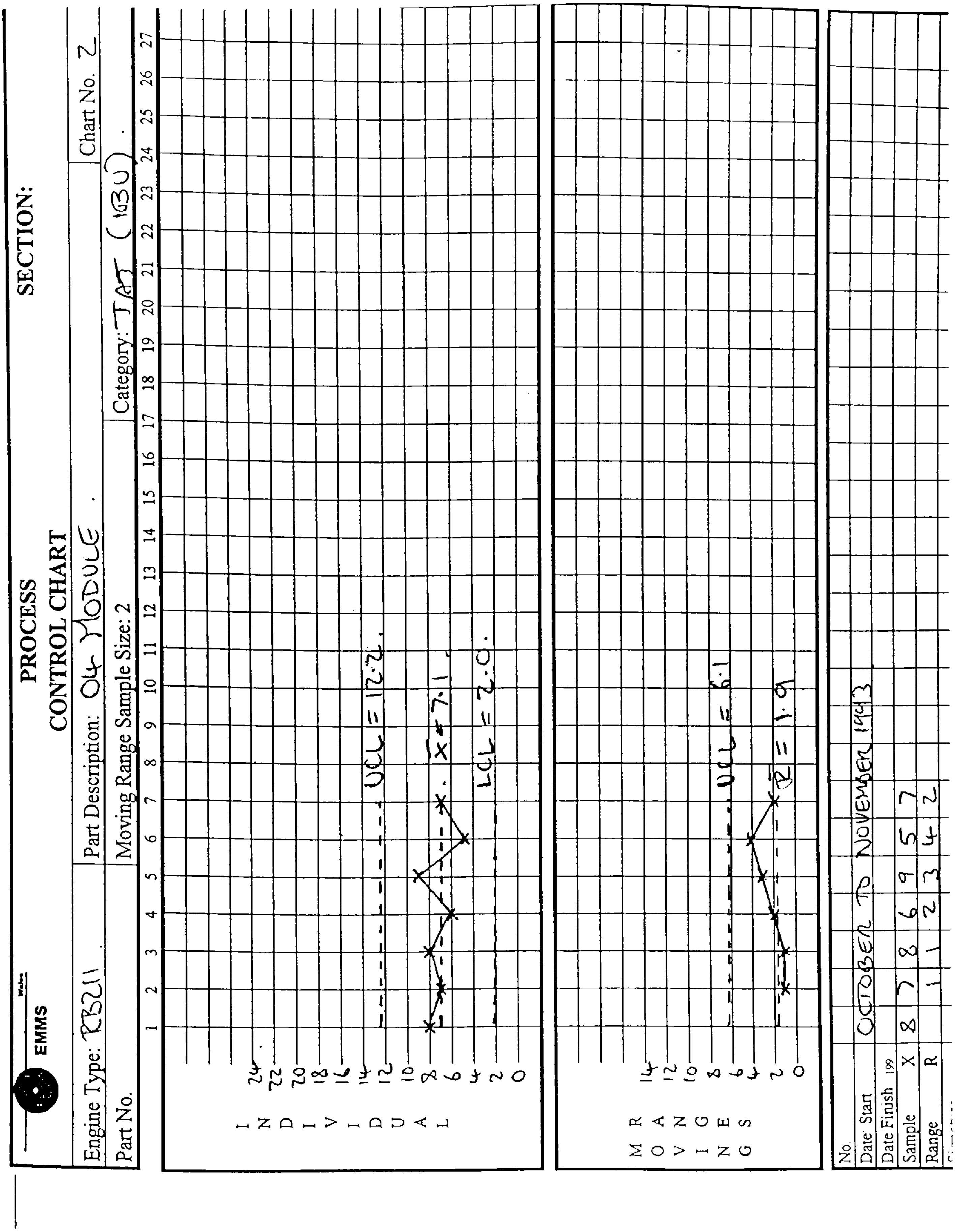

Figure 25 RB211 04 Module Process Control Chart 2

RB 211 04 MODULE STRIP - DVB

CHART 1. JULY - OCTOBER

$\Sigma x_1 = 321$

$\overline{X}_1 = 321/24 = 13.4$

$\overline{R}_1 = 98/23 = 4.3$

$UCL_X = \overline{X}_1 + 3\hat{\sigma}$

$LCL_X = \overline{X}_1 - 3\hat{\sigma}$

where $\hat{\sigma} = \overline{R}/d_2 = 4.3/1.13 = 3.8$

$3\sigma = 11.4$

$UCL_X = 13.4 + 11.4 = 24.8$

$LCL_X = 13.4 - 11.4 = 2.0$

$LCL_R = D_3\overline{R}_1 = 0$

$UCL_R = D_4\overline{R}_1 = 3.23 \times 4.3 = 13.9$

CHART 2. OCTOBER - NOVEMBER

$\Sigma x_2 = 50$

$\overline{X}_2 = 50/7 = 7.1$

$\overline{R}_2 = 13/7 = 1.9$

$\hat{\sigma}_2 = \overline{R}_2/d_2 = 1.9/1.12 = 1.7$

$3\hat{\sigma}_2 = 5.1$

$UCL_R = \overline{X}_2 + 3\sigma_2 = 7.1 + 5.1 = 12.2$

$LCL_R = \overline{X}_2 - 3\hat{\sigma}_2 = 7.1 - 5.1 = 2.0$

$LCL_R = D_3\overline{R}_2 = 0$

$UCL_R = D_4\overline{R}_2 = 3.23 \times 1.9 = 6.1$

Figure 26 Calculations for RB211 04 Module Process Control Charts 1 and 2 a sample size of one. i.e. each engine / modules TAT is marked as a point. The charts were constructed using all the historical data that existed, and then updated on a weekly basis to add all the engines / modules that had passed through the system during the given time period.

Any significant change in the value of R will give an indication as to the changes in the values of the range. The lower the value of R, the lower the variation in the system. What can be seen from the control charts of the RB211 modules, particularly the 04 and 05 modules is some quite significant reductions in the value of R. The value of R drops from 2.88 to 1.54, then increases to 4.67 and then reduces to 1.87. The aim was to keep the R value under 2. The significant rise of the R value (Figure 24. Point 22) was put down to two particular special causes. These being causes outside the normal delays of the system. The cause being two modules having special workscopes involving the use of the blade tip grinding machine (BTG) and another module waiting for handling equipment in the strip area due to the amount of work in progress in the rest of the facility.

6.7.1 The Use of Statistical Process Control (SPC) Charts

To be sure that the introduction of the project was successful there needed to be some form of measurement. The TAT was marked down every time an engine was completed in the DVB but there needed to be some form of analysis as to whether the TAT was within the normal variation limits of the system or whether it was outside the limits.

The key measurement to monitor any improvements is time. There was a certain amount of historical data on engine turn times through the IBU and this was plotted onto a control chart. Example charts are given in Figures 24 and 25. Figure 24. shows the system was stable and within statistical control with only common causes of variation present. Figure 25. shoes the same, with the system being in statistical control. Figure 25. shows the results for 04 modules after the introduction of the Bay in a Day project. Where X is reduced by virtually 13.4 to 7.1 days and R is reduced from 4.3 to 1.9 showing that the improvements in the system are directly attributable to work in this project. Figure 26. showing the calculations used to produce the control limits given in Figures 24 and 25.

The resulting charts produced are shown in Appendix 8. What these actually show are the TAT for engines and modules. Of particular relevance are the charts detailing the progress of RB211 modules. These charts were being kept updated by the author with feedback being given on a weekly basis to those involved in the throughput of those modules in the detail view bay. The eventual aim is for these charts to be placed in the work areas with the company members updating the charts themselves.

What is very noticeable on the charts is the amount of variation that occurs between the minimum time and the maximum time. The first chart in Appendix 8 titled JT9 (1) has an average ($\bar{X}$) of 15.98 days but the variation ($\bar{R}$) can be up to 21 days. This range is extremely high. Lawrence S. Aft (1988) states that 'The goal of any quality program in any organisation is to continue to improve by reducing the variability around the target. The less variability there is, the more consistency there will be. This will lead to the ultimate goal of increasing productivity.'

What is required is a technique of measuring this variation. Aft continues 'SPC would be better defined as the statistical and problem-solving measures used for continuously improving quality. And by continuing to improve quality, we mean continuing to reduce the variability about the target.' The use of the technique of SPC to track and measure the TAT for engines and modules would show if any improvement had been made to the system. Here we would see not only a reduction in turn times, but also a reduction in variability.

6.7.2 Other Uses for SPC Charts

The work done on measuring TAT goes hand in hand with another SPC project introduced, to actually measure and record the actual man-hours spent on the job by the company members. This has been introduced for the RB211 04 module with the author collecting the data of the Job Time Recording (JTR) cards. This is the first step to introduction of SPC onto the shopfloor where the company members can measure the actual time on the job to record variance, and the reasons for this variance.

The amount of time spent away from the job has also been cited as a major cause for delays in completing the detail inspection of modules and has a direct affect on the 'Bay in a Day' concept. Taking the inspector away from the job means the module will not be completed in the time scales allowed. In a busy week where the same team are being used every day, any delay in completing the module in the allotted time period can be disastrous as it has a knock on affect on the other modules that are planned for that week. The project is still in its infancy but when fully introduced will provide a useful source of information when costing an engine and also for the planning for the amount of work that is required when scheduling an engine into the detail view bay.

6.8 The Use of the Bay in a Day Theory for Engine Implementation

It was discussed with various company members as to whether the 'Bay in a Day' theory of splitting the major modules could be introduced onto the other engine types such as the JT9 and the Olympus. The main candidates for introduction being the JT9 B,C and D modules and the Olympus 061 module. These are the longest to complete the detail inspection process.

The requirements laid out for the successful introduction of the 'Bay in a Day' theory were the splitting of the manuals and the splitting of the paperwork so as to allow the formation of individual workpacks. This was a relatively simple exercise for the RB211 engines with the paperwork and the manuals being sub-divided already. In the case of the JT9 engine, a major problem was identified in the process of splitting the modifications (mods)system. This was a purely technical problem with the problem being the make- up of the system.

CHAPTER 7 FINAL DISCUSSION

7.1 Review of the Project

The aim of this final chapter is to discuss the project and the results up to April 1994, when the author changed position in the company to work on the introduction of the new GE90 engine into the facility.

The project to initially reduce lead times was started by the author in June 1992, this fitting in with the company mission *'To be acknowledged as the world leader in engine services.'* The need to reduce TAT was seen as essential to the survival and expansion of EMMS. The project initially began with identifying the problem and then identifying how to tackle it. This eventually became a project to justify the commencement of a simulation study. The reason for this was the need to not only understand the workflow in each shop but to understand the relationship between each of the shops in the IBU.

As a result a simulation team was formed and the project commenced, the aim being to use simulation to investigate the work throughput of the IBU. A great deal of time was spent on the model, especially in the model validation phase until the team was happy with the results being produced by the simulation model. This now meant that the model could be used for investigations into changes that were felt to be of benefit in the search for reduced TAT . Detailed discussions of these scenarios have been given in the preceding chapters.

It was through the 'what - if' investigations that there seemed to be a common problem, this being the speed at which work passed through the detail view bay. Depending upon the WIP level, queuing was seen as normal in front of the DVB. In discussion with the supervisors of the area this was the normal situation. Also this shop had the slowest throughput of all the shops in the IBU, with work taking up to eight days to pass through the DVB.

A KAIZEN exercise was run in the DVB in an attempt to reduce the amount of waste time. There was a great deal of time spent working on other jobs such as cardwork, or working on queries for the build line. The emphasis always being that the work on the build line and the card work was far more important than the flow of modules through the IBU. Some work was done to address this through the introduction of a schedule whereby two inspectors were detailed to answer all queries, leaving the other inspectors to concentrate on their job.

One item that did arise from the simulation and the KAIZEN exercise was the need to speed the work through the DVB. This was looked at to determine if it was possible to split the modules down into mini-modules each with a separate workpack comprising of all the information the inspector needs to complete his inspection on the module. This would enable teams of men working on the same module, the target being set to detail inspect modules in a day; *the Bay in a Day project.*

This project was implemented initially on the RB211 - 05 module, which initially took five days to inspect and was now reduced to one day. Since the implementation of this project the 05 module has consistently been below ten days for the monthly average, compared to averages of 11 to 14 days. This concept was introduced onto the other RB211 modules, except the 06 module. As a result all modules working with this system have given consistent averages of below ten days. As the target to complete the work throughput of the IBU is twelve days this is below the target. This concept is currently being introduced on the other engine types. The first 'Bay in a Day' project on the JT9 B, C, and D modules is due in May 1994 with the other engine types to follow. This project is now seen as essential to achieving the target of twelve days for strip to detail inspection.

With this change in working practices the need for scheduling is now seen as essential. The co-ordination of the work teams in the DVB is a necessity for achieving the throughput of modules and if this is allowed to lapse then the concept will not work and the TAT levels will rise again. A great deal of scheduling discipline is needed to put modules on hold until there is a full team available to be able to complete the module in a day.

The affect on the company members involved in the changes was good, the majority of the inspectors embraced the idea of working in teams, preferring it, as their job changed every day, rather than spending all week on the same module. Controls were instigated into the system to analyse the reasons why modules did not complete in the specified time limit. This to be used as a continuous improvement process to remove problems from the system.

7.2 The Success of the Project

The aim of the project given stated in chapter 3.2.7 was to ***'look at the present system in respect to scheduling, shift work, queuing and work mix and then to investigate the changes needed to be made to allow the system to achieve a constant TAT of 11 days for all items passing through the IBU.*** Figures 27. to 31. show the monthly average TAT against the monthly number of modules passing through the IBU for RB211 01, 02, 03, 04 and 05 modules. These graphs show the average TAT for all modules.

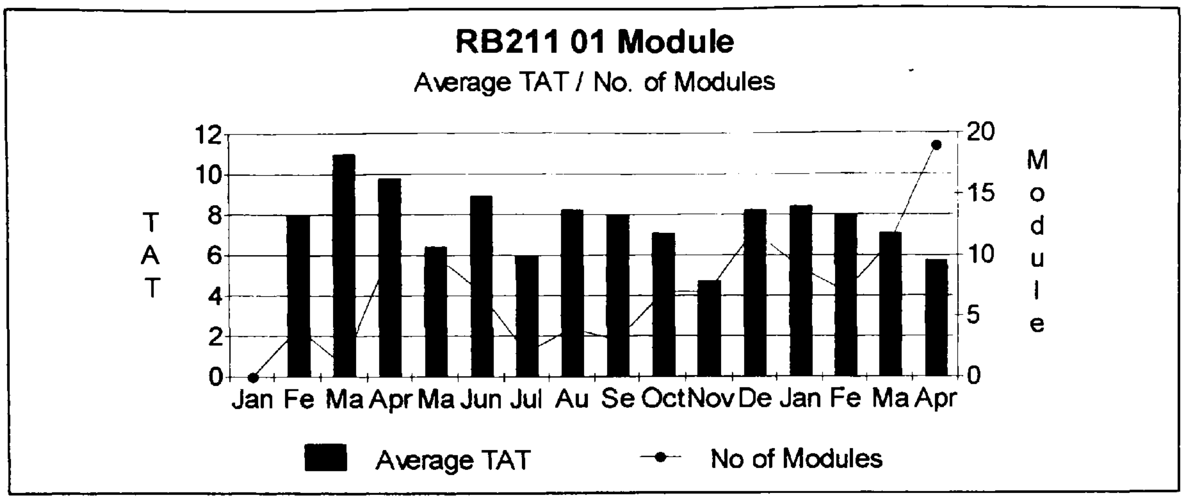

Figure 27. RB211 01 Module Average TAT / No. of Modules 1993/94

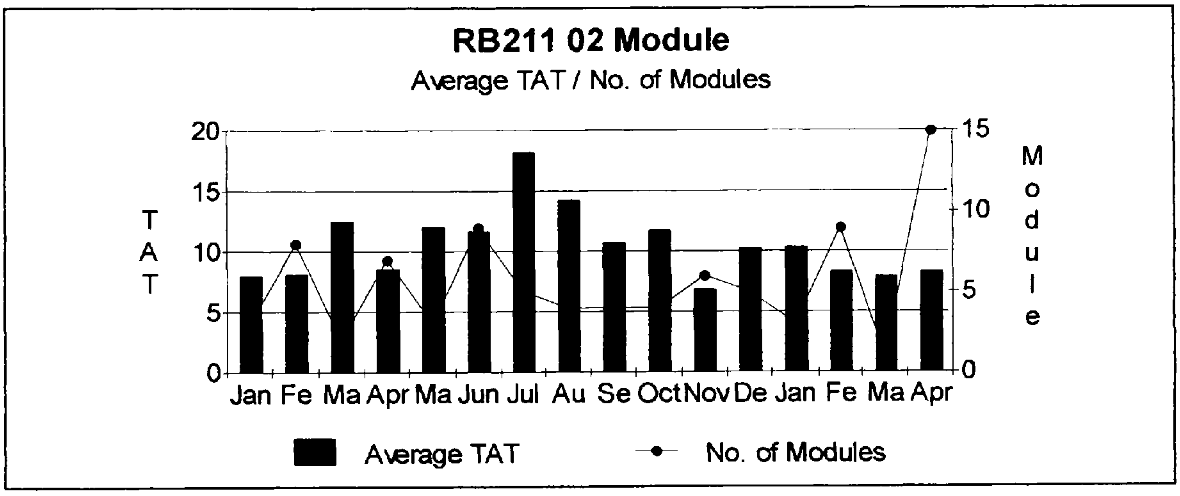

Figure 28. RB211 02 Module Average TAT / No. of Modules 1993/94

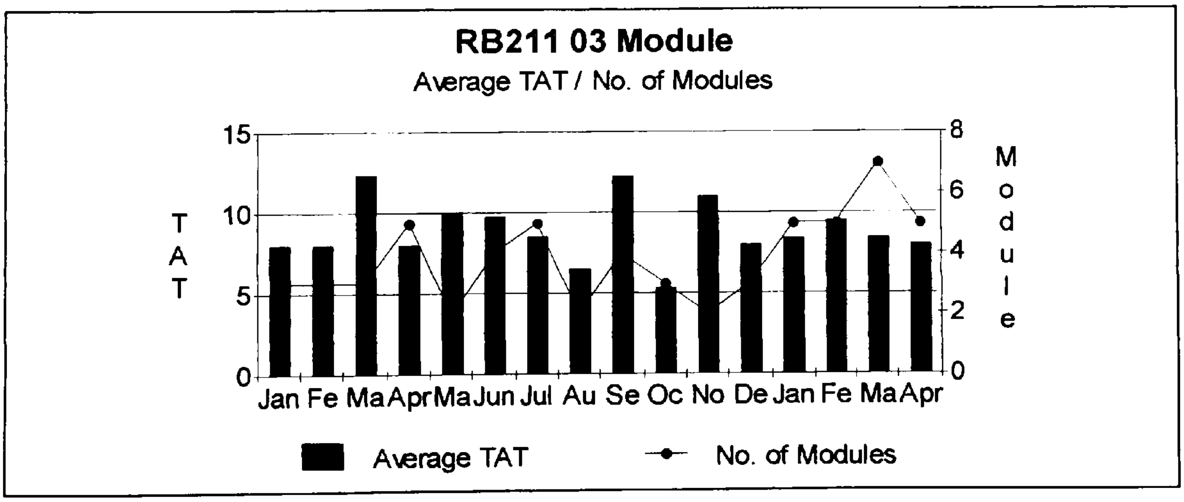

Figure 29. RB211 03 Module Average TAT / No. of Modules 1993/94

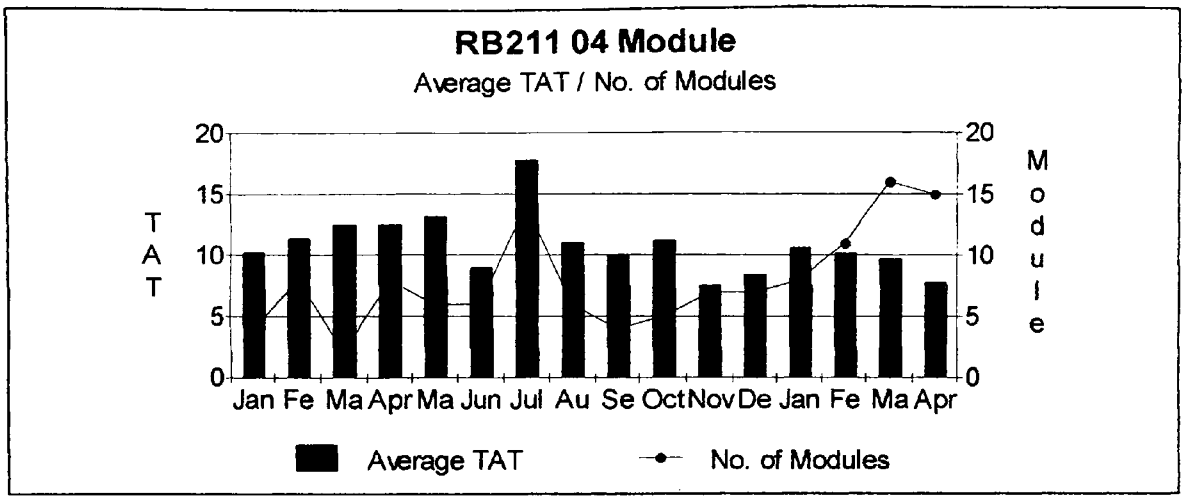

Figure 30. RB211 04 Module Average TAT / No. of Modules 1993/4

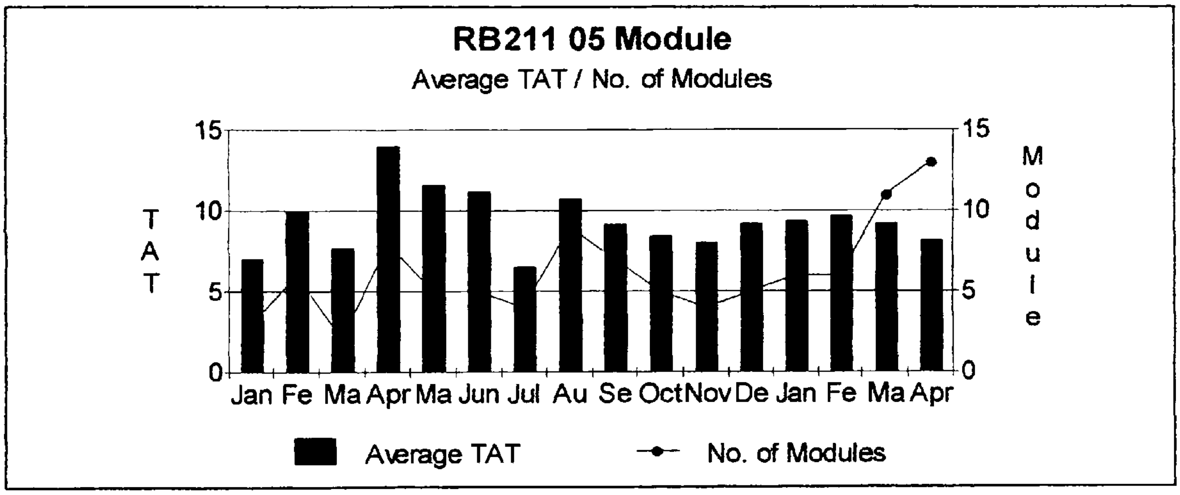

Figure 31. RB211 05 Module Average TAT / No. of Modules 1993/4

Particular emphasis must be placed on the 1994 March / April figures where there is a significant rise in the number of modules passing through the system, with the TAT either remaining constant or reducing.

The aim of the project was to reduce TAT for all items passing through the IBU to 11 days. This includes all the engine types: JT8, JT9, CFM56 and Olympus. As discussed in chapter 6.8 the major barrier to the introduction of the bay in a day concept to engine implementation was the problems in changing the mods system. This allowed the introduction of individual workpacks for the mini modules that would be required for the engine modules. The theory of the project means that TAT for all engines should be reduced quite significantly.

The overall affect on the business was considerable, with BA requiring a large number of RB211 524 G+H engineers to be worked in a very short space of time. Without the introduction of the bay in a day project the IBU would not have been able to cope with the demands placed on it, and some of the work shipped to other engine overhaul agencies.

The reduction of times for the DVB are given in Table 12.

Table 12. Reduction in Times Taken to Inspect RB211 Modules

Module RB211	Orignal Time (DAYS)	New TIme (DAYS)	% Change
O1	1	1	0
O2	3	1	66
O3	2	1	50
O4	4	1	75
O5	5	1	80

Goldratt (1986) states that 'Focused application of the right productivity improvement technique reduces disruptions and eliminates the most important holes in our buffers. As the buffers are decreased, since they contain the majority of the work- in- progress inventory, the competitive edge of the plant is increased. Lead times, operating expense and inventory investment will decrease while quality, due- date performance and the speed of introducing improved products will increase.' Whilst this is aimed at the normal production industry, areas are directly relevant to the repair and overhaul business. Goldratt continues 'the elimination of the most important sources of disruption and the increased volume will change our plant and how and where we should focus our efforts.' This is where the project focused, on removing the disruptions from the system.

7.3 Cost Benefits to the Business

In order to analyse the effect of TAT savings on the business it is necessary to give the worst case scenario. If EMMS does not produce an engine for the customer in the required time, the customer will lease an engine and charge this to EMMS at a daily rate of $2000. Therefore each day saved on the TAT of an engine can save $2000. For the RB211 05 module which saved four days, this equates to a saving of $8000 on an engine that could have been late.

For the customer the benefits of a low TAT equate to a reduction in the number of engines that need to be owned. This is very significant as a new single engine costs in excess of a million pounds. So an overhaul agency that can offer a consistently low TAT will maintain its current customers and win new customers.

7.4 Summary

The aim of the project was to reduce the lead time of engines passing from strip to detail inspection. With the introduction of the 'Bay in the Day' project lead times were significantly reduced. The example given in Figures 24 and 25. for the RB211 04 module shows a reduction in average turn around times from 13.4 days to 7.1 days. Coupled with this is the increase of the predictability of the system which is shown by the reduction of the R values which reduce from 4.3 to 1.9.

Coupled with the lead time reduction there were other benefits from the introduction of this project. SPC charts were introduced to the shop floor as a measure, and work done in introducing the company members to the understanding and use of the forms. Another major benefit has been the introduction of team working to the shop floor as an alternative way of working. This has worked very well and has fitted in with the GE corporate strategy.

7.5 Recommendations for Future Work

The initial recommendation is that the work is continued to bring all the engines into the bay in a day concept. This will only be possible when the mods systems has been adjusted to allow the production of individual workpacks. The training program set up needs to be continued and adhered to so as to allow the DVB the flexibility it requires to be able to deal with the widest range of engines / modules.

The work done on the reduction of time between engine inputs needs to be implemented but only when the DVB has the capacity to pull work through the IBU. This should aid further in the reduction of TAT.

When both the DVB and the strip shop have developed their working practices to the theories outlined then some time will need to be spent analysing the two process based operations. Cleaning and crack detect will need investigating to understand whether they have the capacity to cope with the workload if engines are inputted every two days.

Work must be done on analysing where the new GE90 engine is going to fit in with these processes. Especially with all the new technology that has appeared on this engine.

6.7 Lessons to be Learnt

In carrying out the project to reduce lead times in aero engine overhaul there are a number of lessons that can be learned from the techniques employed. These lessons are general in nature and can be applied to any project examining processes, capacity constraints, scheduling techniques, etc.

6.7.1 Simulation Modelling

Simulation modelling was initially used to look at the process as a whole rather than to look at a series of individual shops. What was underestimated was the complexity and the time involved in modelling a large process. This is something that cannot be stressed enough. Modellers must allow a great deal of time to gather accurate data and to create the model. The term accurate data is used to indicate that the standard hours given in the companies costing structure may be inaccurate so it is important to gather the data from the shopfloor.

One of the powers of simulation modelling is the fact that it can be used as a very persuasive tool to enrol senior management. That is recommendations coming from simple tools and experiments can have a certain lack of credibility. This is due to their simplicity. Many organisations have the prevailing culture that complexity must be right because it is complex ! Again the power of simulation modelling as a presentation medium to convince senior management of the need for change and the target area for change was a very important lesson.

At a very basic level, before embarking on a very complex and time consuming activity such as simulation modelling various simple process models and paper / spreadsheet simulations could be created and run. This would give very much the same result as the large scale simulation model by focusing the need for change on a particular area. It is important to investigate the simple ways of examining linked processes before heading straight for the very complex route.

6.7.2 The Formation of Teams

One of the major benefits of this project was the formation of work teams on the shop floor. As someone relatively new and young in the organisation this could have been a major blocker to the implementation of the project. To overcome this a great deal of time was spent on the shop understanding the problems and pitfalls that were part of the everyday working environment. This included such simple things as making sure all the inspection manuals were placed in the correct cupboard overnight to allow for easy location the following morning. Many small project were implemented to make life as easy as possible for the shopfloor employees and to show that you were on their side. With all these helpful project implemented it was then easier to introduce the change in working practices. It must be stressed that it is crucial to bring the people who are going to implement the recommended changes with you. If they feel at all as if the changes are going to be imposed then they will block it and the project will fail.

6.7.3 Measurement Techniques

In introducing measurement techniques it is important to show the value of these to the shopfloor. This was done through the use of SPC charts where the items being measured that were out of control and had a cause attributed it to them, were sent to the area that had the 'blame' and a response extracted as to the reason for the delay. This proved the worth of measuring to the people who were in fact being measured.

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List of Appendices: **Page Number**

Appendix 1

List of simulation software available

Review of Software Available

Name	Hardware Reqd	Size of Model Allowed	Logic	Manufacturing Based	Outputs	Training and Support	Demo.
WITNESS	PC, +Math Co-Pr	Large	Model Machines	Yes	Tabular	Training Extra Cost	Yes
					Export	Support good but costly	
Pro-Model	PC	100,000 Parts	Model Components	Yes	Graphical,	Training Included	Yes
		2,000 Operations			Tabular	Updates 750 Per Annum	
		500 Transporters					
Syspack VS7	PC	200 Entities	Activity Cycle Diagram	Multi-Purpose	Graphical	Consultency	No
		400 Activities			Indicator		
		400 Queues					
Business	Workstation	Large 3D	Model Machines	Yes	Graphical	Consultency	Yes
Simulation							
SIMFACTORY	PC	Large	Workflow	Yes	Graphical	Free Training	No
					(Export)		
PC-Model	PC	Hardware Dependent	Programming	Multi-Purpose	Tabular		Yes

Appendix 2

Listing of all the figures used to construct the simulation model of the IBU

Bulk / Detail Strip

All times given are total manhours

JT9	*TIMES:*		*JT8*	*TIMES*
BULK	40		BULK	20
A	20		A	10
B	64		B	10
C	16		C	5
D	15		D	1
E	6		E	2
F	12		F	1
G	3		H	5
H	8		J	8
J	18		K	5
K	12		L	1
L	4		V	1
V	4			
OLYMPUS	*TIMES*		*RB211*	*TIMES*
BULK	40		O1 BULK	3
O1	7		O1	8
O2	30		O2 BULK	3
O3	15		O2	45
O4	12		O3 BULK	3
O5	1		O3	12
O61	39		O4 BULK	3
O62	20		O4	60
O7	2		O5 BULK	3
O8	4		O5	53
O9	2		O6	12
O10	3			
O11	4			
O12	15			

Cleaning Bay

All times given are total manhours

	Tank	*Machine*	*Hand*		*Tank*	*Machine*	*Hand*
JT9	*Times*	*Times*	*Times*	*JT8*	*Times*	*Times*	*Times*
A	3	4	2	A	2	3	2
B	8	3	2	B	4	1	2
C	6	7	2	C	1	1	2
D	6	11	2	D	4	3	2
E	2		4	E	0	0	4
F	2		4	F	2	0	4
G	1	5	2	H	1	1	2
J	6	3	2	J	2	0	2
K	6		2	K	4	0	2
L	6	1	2	L	4	1	2
V	4	3	2	V	4	0	2
	Tank	*Machine*	*Hand*		*Tank*	*Machine*	*Hand*
OLYMPUS	*Times*	*Times*	*Times*	*RB211*	*Times*	*Times*	*Times*
O1	4		2	O1	4	7	3
O2	6		6	O2	4	7	2
O3	3		2	O3	6	0	2
O4	6		6	O4	12	3	4
O5	6		6	O5	12	5	2
O61	8		16	O6	4	3	4
O62	6		4				
O7	6		0				
O8	0		2				
O9	6		2				
O10	0		2				
O11	6		3				
O12	4		4				

Crack Detection

All times given are total manhours

	Front-	Back-	Electro-			Front-	Back-	Electro-	
JT9	*Line*	*Line*	*Static*	*Mpi*	*JT8*	*Line*	*Line*	*Static*	*Mpi*
A	3		5	1	A	16			4
B	12	24	15		B	4	12		2
C	8		4		C	4	3		1
D	8		2		D	12	8	2	6
E		3			E				
F					F				1
G		3	2		H		3		2
J	3		3	1	J		2	2	3
K		5	5		K		4	2	3
L		4	3	4	L	2	5		1
V		6			V		7	2	2
	Front-	*Back-*	*Electro-*			*Front-*	*Back-*	*Electro-*	
OLYMPUS	*Line*	*Line*	*Static*	*Mpi*	*RB211*	*Line*	*Line*	*Static*	*Mpi*
O1		4	2		O1	3		2	1
O2	20			6	O2	3	6	12	4
O3		2		4	O3		2	3	2
O4				4	O4	4	12		2
O5				4	O5	4		10	4
O61	32			8	O6		2		7
O62	2	6	2	2					
O7		3							
O8									
O9									
O10									
O11	4		3						
O12	4	3	2						

Detail View Bay

All times given are total manhours

JT9	*TIMES:*		*JT8*	*TIMES*
A	10		A	16
B	52		B	12
C	24		C	8
D	14		D	14
E			E	
F			F	
G	14		H	12
H			J	10
J	12		K	14
K	22		L	8
L	14		V	14
V				
OLYMPUS	*TIMES*		*RB211*	*TIMES*
O1	4		O1	10
O2	18		O2	17
O3	11		O3	17
O4			O4	24
O5			O5	21
O61	24			
O62	16			
O7				
O8	2			
O9	4			
O10	3			
O11	4			
O12	15			

Appendix 3

Actual TAT figures

JT9 STRIP TO REPLENISMENT

COMPLETION DATA FROM JULY 1993

AVERAGE TAT 06-May-94 15.98 PAGE 1 OF 2

OP	ENGINE No.	TYPE	RECIEPT DATE	PLANNED STRIP DATE	ACT STRIP START	VAR	STRIP TARGET	D.V.B. TARGET	ACTUAL COMPLETE	ACTUAL T.R.T.	RUNNING AVERAGE	MONTHLY AVERAGE
BA	662856	JT9	02-Jul	07-Jul	07-Jul	0	11-Jul	19-Jul	23-Jul	16		
BA	662447	JT9	30-Jun	07-Jul	12-Jul	5	11-Jul	19-Jul	25-Jul	13	14.50	
BA	685863	JT9	09-Jul	21-Jul	21-Jul	0	25-Jul	02-Aug	08-Aug	16	15.00	
EV	685936	JT9	28-May	18-Jul	18-Jul	0	22-Jul	30-Jul	10-Aug	23	17.00	
SS	663036	JT9	12-Jul	27-Jul	27-Jul	0	31-Jul	08-Aug	16-Aug	20	17.60	AUGUST
PK	686030	JT9	08-Jul	05-Aug	05-Aug	0	09-Aug	17-Aug	24-Aug	19	17.83	AVERAGE
BA	685821	JT9	22-Jul	08-Aug	10-Aug	2	12-Aug	20-Aug	24-Aug	14	17.29	18.40
BA	685632	JT9	06-Jul	02-Aug	02-Aug	0	06-Aug	14-Aug	07-Sep	36	19.63	
SS	662997	JT9	02-Aug	13-Aug	13-Aug	0	17-Aug	25-Aug	03-Sep	21	19.78	
BA	685822	JT9	20-Jul	16-Aug	16-Aug	0	20-Aug	28-Aug	05-Sep	20	19.80	
EV	662970	JT9	27-Jul	19-Aug	19-Aug	0	23-Aug	31-Aug	07-Sep	19	19.73	
EV	662969	JT9	04-Aug	22-Aug	22-Aug	0	26-Aug	03-Sep	14-Sep	23	20.00	
BA	663022	JT9	15-Aug	25-Aug	25-Aug	0	29-Aug	06-Sep	15-Sep	21	20.08	
BA	685987	JT9	30-Jul	01-Sep	01-Sep	0	05-Sep	13-Sep	18-Sep	17	19.86	SEPTEMBER
BA	662441	JT9	03-Aug	13-Sep	13-Sep	0	17-Sep	25-Sep	26-Sep	13	19.40	AVERAGE
KU	686105	JT9	07-Sep	20-Sep	19-Sep	-1	24-Sep	02-Oct	30-Sep	11	18.88	20.11
EV	662268	JT9	07-Sep	22-Sep	22-Sep	0	26-Sep	04-Oct	06-Oct	14	18.59	
EV	662497	JT9	07-Sep	24-Sep	24-Sep	0	28-Sep	06-Oct	14-Oct	20	18.67	
PK	685962	JT9	02-Sep	05-Oct	05-Oct	0	09-Oct	17-Oct	18-Oct	13	18.37	
BA	662857	JT9	24-Aug	11-Oct	09-Oct	-2	15-Oct	23-Oct	22-Oct	13	18.10	
5Y	662853	JT9	03-Oct	13-Oct	09-Oct	-4	17-Oct	25-Oct	21-Oct	12	17.81	OCTOBER
BA	662304	JT9	04-Sep	27-Sep	27-Sep	0	01-Oct	09-Oct	13-Oct	16	17.73	AVERAGE
PK	695605	JT9	20-Sep	14-Oct	13-Oct	-1	18-Oct	26-Oct	27-Oct	14	17.57	14.57
BA	662352	JT9	28-Sep	20-Oct	20-Oct	0	24-Oct	01-Nov	04-Nov	15	17.46	
PK	685909	JT9	29-Sep	26-Oct	24-Oct	-2	30-Oct	07-Nov	08-Nov	15	17.36	
BA	662357	JT9	07-Oct	01-Nov	29-Oct	-3	05-Nov	13-Nov	11-Nov	13	17.19	
BA	663021	JT9	16-Oct	04-Nov	02-Nov	-2	08-Nov	16-Nov	14-Nov	12	17.00	

JT9 COMPLETION DATA AVERAGE TAT

STRIP TO REPLENISMENT FROM JULY 1993 06-May-94 15.98 PAGE 2 OF 2

OP	ENGINE No.	TYPE	RECIEPT DATE	PLANNED STRIP DATE	ACT STRIP START	VAR	STRIP TARGET	D.V.B. TARGET	ACTUAL COMPLETE	ACTUAL T.R.T.	RUNNING AVERAGE	MONTHLY AVERAGE
PK	685976	JT9	19-Oct	02-Nov	04-Nov	2	06-Nov	14-Nov	22-Nov	18	17.04	NOVEMBER
KU	662741	JT9	21-Oct	05-Nov	06-Nov	1	09-Nov	17-Nov	22-Nov	16	17.00	AVERAGE
BA	685742	JT9	16-Oct	10-Nov	06-Nov	-4	14-Nov	22-Nov	23-Nov	17	17.00	15.14
KU	698599	JT9	30-Oct	23-Nov	23-Nov	0	27-Nov	05-Dec	06-Dec	13	16.87	
BA	685896	JT9	11-Nov	28-Nov	23-Nov	-5	02-Dec	10-Dec	08-Dec	15	16.81	DECEMBER
BA	662414	JT9	25-Oct	30-Nov	04-Dec	4	04-Dec	12-Dec	15-Dec	11	16.64	AVERAGE
BA	662492	JT9	08-Nov	04-Dec	06-Dec	2	08-Dec	16-Dec	20-Dec	14	16.56	13.25
BA	662488	JT9	11-Nov	10-Dec	12-Dec	2	14-Dec	22-Dec	05-Jan	24	16.77	
BA	685644	JT9	19-Nov	19-Dec	18-Dec	-1	23-Dec	31-Dec	06-Jan	19	16.83	
BA	685665	JT9	03-Dec	29-Dec	29-Dec	0	02-Jan	10-Jan	13-Jan	15	16.78	JANUARY
BA	662493	JT9	24-Dec	09-Jan	10-Jan	1	13-Jan	21-Jan	20-Jan	10	16.61	AVERAGE
BA	685990	JT9	12-Jan	17-Jan	19-Jan	2	21-Jan	29-Jan	31-Jan	12	16.49	16.00
PK	695734	JT9	18-Jan	25-Jan	24-Jan	-1	29-Jan	06-Feb	05-Feb	12	16.38	
CO	686028	JT9	28-Dec	01-Feb	01-Feb	0	05-Feb	13-Feb	11-Feb	10	16.22	FEBRUARY
BA	662888	JT9	24-Jan	05-Feb	08-Feb	3	09-Feb	17-Feb	20-Feb	12	16.12	AVERAGE
BA	662335	JT9	31-Jan	09-Feb	11-Feb	2	13-Feb	21-Feb	25-Feb	14	16.07	12.00
BA	685823	JT9	14-Feb	24-Feb	24-Feb	0	28-Feb	08-Mar	07-Mar	12	15.98	MARCH
SS	662767	JT9	26-Feb	05-Mar	05-Mar	0	09-Mar	17-Mar	21-Mar	17	16.00	AVERAGE
PK	685973	JT9	02-Mar	12-Mar	10-Mar	-2	16-Mar	24-Mar	24-Mar	15	15.98	14.67
BA	685715	JT9	09-Mar	19-Mar	23-Mar	4	23-Mar	31-Mar	08-Apr	17	16.00	APRIL
BA	686065	JT9	24-Mar	29-Mar	29-Mar	0	02-Apr	10-Apr	12-Apr	15	15.98	AVERAGE
BA	685737	JT9	21-Mar	06-Apr	06-Apr	0	10-Apr	18-Apr	20-Apr	15	15.96	15.67
BA	685719	JT9	21-Mar	16-Apr	15-Apr	-1	20-Apr	28-Apr	01-May	17	15.98	

JT8 COMPLETION DATA AVERAGE TAT

STRIP TO REPLENISHMENT FROM JANUARY 1993 06-May-94 15.81

OP	ENGINE No.	TYPE	RECIEPT DATE	PLANNED STRIP DATE	ACT STRIP START	VAR	STRIP TARGET	D.V.B. TARGET	ACTUAL COMPLETE	ACTUAL T.R.T.	RUNNING AVERAGE	MONTHLY AVERAGE
BA	709236	JT8	09-Dec	29-Dec	22-Dec	-7	02-Jan	10-Jan	18-Jan	27		JANUARY
BA	709238	JT8	14-Jan	28-Jan	22-Jan	-6	01-Feb	09-Feb	12-Feb	21	24.00	27.00
BA	709232	JT8	20-Jan	19-Feb	20-Feb	1	23-Feb	03-Mar	05-Mar	13	20.33	FEBRUARY
BA	702801	JT8	10-Feb	26-Feb	02-Mar	4	02-Mar	10-Mar	12-Mar	10	17.75	21.00
BA	709241	JT8	16-Feb	10-Mar	10-Mar	0	14-Mar	22-Mar	24-Mar	14	17.00	MARCH
BA	709250	JT8	28-Feb	25-Mar	29-Mar	4	29-Mar	06-Apr	16-Apr	18	17.17	12.33
BA	702840	JT8	07-Apr	30-Apr	30-Apr	0	04-May	12-May	15-May	14	16.71	APRIL
BA	702902	JT8	20-Apr	09-May	09-May	0	13-May	21-May	24-May	15	16.50	18.00
BA	709248	JT8	21-Apr	12-May	12-May	0	16-May	24-May	29-May	17	16.56	MAY
BA	702864	JT8	11-Jun	15-Jun	15-Jun	0	19-Jun	27-Jun	28-Jun	13	16.20	15.33
BA	702904	JT8	14-Jul	24-Jul	23-Jul	-1	28-Jul	05-Aug	05-Aug	13	15.91	JUNE
BA	707919	JT8	24-Jul	29-Jul	29-Jul	0	02-Aug	10-Aug	16-Aug	18	16.08	13.00
BA	717101	JT8	29-Jul	09-Aug	09-Aug	0	13-Aug	21-Aug	04-Sep	26	16.85	JULY
BA	709249	JT8	11-Aug	04-Sep	03-Sep	-1	08-Sep	16-Sep	29-Sep	26	17.50	
BA	702871	JT8	12-Sep	16-Sep	16-Sep	0	20-Sep	28-Sep	05-Oct	19	17.60	AUGUST
TZ	688183	JT8	04-Oct	08-Oct	08-Oct	0	12-Oct	20-Oct	24-Oct	16	17.50	15.50
BA	709190	JT8	14-Oct	29-Oct	25-Oct	-4	02-Nov	10-Nov	05-Nov	11	17.12	SEPTEMBER
TZ	707254	JT8	26-Oct	01-Nov	28-Oct	-4	05-Nov	13-Nov	11-Nov	14	16.94	26.00
BA	702820	JT8	07-Oct	07-Nov	07-Nov	0	11-Nov	19-Nov	23-Nov	16	16.89	OCTOBER
BA	702880	JT8	19-Oct	02-Dec	29-Nov	-3	06-Dec	14-Dec	15-Dec	16	16.85	17.50
TZ	709552	JT8	01-Dec	11-Dec	10-Dec	-1	15-Dec	23-Dec	21-Dec	11	16.57	NOVEMBER
BA	702819	JT8	23-Nov	21-Dec	20-Dec	-1	25-Dec	02-Jan	06-Jan	17	16.59	13.67
BA	702893	JT8	09-Dec	04-Jan	05-Jan	1	08-Jan	16-Jan	18-Jan	13	16.43	DECEMBER
TZ	707914	JT8	04-Jan	12-Jan	13-Jan	1	16-Jan	24-Jan	28-Jan	15	16.38	13.50
BA	702917	JT8	25-Jan	23-Feb	22-Feb	-1	27-Feb	07-Mar	04-Mar	10	16.12	JANUARY
BA	702818	JT8	04-Mar	12-Mar	14-Mar	2	16-Mar	24-Mar	25-Mar	12	15.96	15.00
BA	702909	JT8	02-Mar	21-Mar	21-Mar	0	25-Mar	02-Apr	01-Apr	12	15.81	MARCH
BA	702829	JT8	14-Mar	26-Mar	26-Mar	0	30-Mar	07-Apr	08-Apr	14	15.75	11.00
TZ	688291	JT8	29-Mar	01-Apr	01-Apr	0	05-Apr	13-Apr	20-Apr	20	15.90	
TZ	715306	JT8	29-Mar	10-Apr	12-Apr	2	14-Apr	22-Apr	20-Apr	9	15.67	APRIL
BA	702981	JT8	16-Mar	08-Apr	08-Apr	0	12-Apr	20-Apr	27-Apr	20	15.81	15.00

OLYMPUS COMPLETION DATA AVERAGE TAT

STRIP TO REPLENISHMENT FROM JAN 1993 06-May-94 20.74

OP	ENGINE NO	TYPE	RECIEPT DATE	PLANNED STRIP DATE	ACT STRIP START	VAR	STRIP TARGET	D.V.B. TARGET	ACTUAL COMPLETE	ACTUAL T.R.T.	RUNNING AVERAGE	MONTHLY AVERAGE
BA	CBE094	OLY	10-Dec	13-Dec	16-Dec	3	17-Dec	26-Dec	13-Jan	28		JANUARY
BA	CBE049	OLY	05-Jan	10-Jan	08-Jan	-2	14-Jan	23-Jan	21-Jan	13	20.50	19.00
BA	CBE025	OLY	18-Dec	25-Dec	23-Dec	-2	29-Dec	07-Jan	14-Jan	22	21.00	FEBRUARY
BA	CBX119	OLY	05-Jan	12-Jan	13-Jan	1	16-Jan	25-Jan	26-Jan	13	19.00	
BA	CBX105	OLY	21-Jan	10-Feb	10-Feb	0	14-Feb	23-Feb	2-Mar	20	19.20	MARCH
BA	CBE081	OLY	01-Feb	16-Feb	16-Feb	0	20-Feb	01-Mar	4-Mar	16	18.67	21.00
BA	CBE091	OLY	13-Jan	08-Mar	02-Mar	-6	12-Mar	21-Mar	29-Mar	27	19.86	APRIL
BA	CBE056	OLY	25-Feb	12-Feb	12-Mar	28	16-Feb	25-Feb	4-Apr	23	20.25	18.33
BA	CBE024	OLY	09-Mar	19-Mar	24-Mar	5	23-Mar	01-Apr	9-Apr	16	19.78	MAY
BA	CBE055	OLY	25-Mar	02-Apr	06-Apr	4	06-Apr	15-Apr	22-Apr	16	19.40	23.75
BA	CBE054	OLY	29-Mar	16-Apr	16-Apr	0	20-Apr	29-Apr	6-May	19	19.36	JUNE
BA	CBE048	OLY	04-Apr	28-Apr	28-Apr	0	02-May	11-May	18-May	20	19.42	23.67
BA	CBE028	OLY	04-Apr	21-Apr	21-Apr	0	25-Apr	04-May	26-May	35	20.62	JULY
BA	CBX122	OLY	24-Apr	05-May	05-May	0	09-May	18-May	18-May	21	20.64	
BA	CBE093	OLY	18-May	22-May	22-May	0	26-May	04-Jun	11-Jun	24	20.87	AUGUST
BA	CBE083	OLY	25-May	29-May	28-May	-1	02-Jun	11-Jun	21-Jun	24	21.06	20.00
BA	CBE065	OLY	24-May	07-Jun	02-Jun	-5	11-Jun	20-Jun	25-Jun	23	21.18	SEPTEMBER
BA	CBE024	OLY	06-Jul	15-Jul	15-Jul	0	19-Jul	28-Jul	4-Aug	20	21.11	33.00
BA	CBX105	OLY	23-Jul	16-Aug	17-Aug	1	20-Aug	29-Aug	19-Sep	33	21.74	OCTOBER
BA	CBE088	OLY	30-Jul	07-Sep	07-Sep	0	11-Sep	20-Sep	04-Oct	27	22.00	22.67
BA	CBE027	OLY	05-Sep	10-Sep	11-Sep	1	14-Sep	23-Sep	05-Oct	24	22.10	NOVEMBER
BA	CBE094	OLY	12-Sep	13-Oct	05-Oct	-8	17-Oct	26-Oct	22-Oct	17	21.86	19.00
BA	CBE056	OLY	20-Sep	23-Oct	21-Oct	-2	27-Oct	05-Nov	09-Nov	19	21.74	DECEMBER
BA	CBE048	OLY	29-Oct	21-Nov	20-Nov	-1	25-Nov	04-Dec	08-Dec	18	21.58	19.33
BA	CBE043	OLY	01-Nov	25-Nov	28-Nov	3	29-Nov	08-Dec	17-Dec	19	21.48	
BA	CBE074	OLY	12-Nov	07-Dec	09-Dec	2	11-Dec	20-Dec	30-Dec	21	21.46	
BA	CBE068	OLY	01-Nov	16-Dec	16-Dec	0	20-Dec	29-Dec	16-Jan	31	21.81	

OLYMPUS

STRIP TO REPLENISHMENT

COMPLETION DATA FROM JAN 1993 06-May-94

AVERAGE TAT 20.74

OP	ENGINE NO	TYPE	RECIEPT DATE	PLANNED STRIP DATE	ACT STRIP START	VAR	STRIP TARGET	D.V.B. TARGET	ACTUAL COMPLETE	ACTUAL T.R.T.	RUNNING AVERAGE	MONTHLY AVERAGE
BA	CBE091	OLY	02-Dec	02-Jan	03-Jan	1	06-Jan	15-Jan	18-Jan	15	21.57	JANUARY
BA	CBX118	OLY	02-Dec	07-Jan	08-Jan	1	11-Jan	20-Jan	28-Jan	20	21.52	20.00
BA	CBX119	OLY	10-Dec	14-Jan	14-Jan	0	18-Jan	27-Jan	28-Jan	14	21.27	FEBRUARY
BA	CBE089	OLY	23-Dec	20-Jan	20-Jan	0	24-Jan	02-Feb	04-Feb	15	21.06	15.50
BA	CBE088	OLY	31-Dec	26-Jan	28-Jan	2	30-Jan	08-Feb	13-Feb	16	20.91	MARCH
BA	CBX103	OLY	17-Feb	02-Mar	02-Mar	0	06-Mar	15-Mar	23-Mar	22	20.94	22.00
BA	CBX111	OLY	21-Feb	13-Apr	11-Apr	-2	17-Apr	26-Apr	24-Apr	14	20.74	APRIL
												14.00

DATE 06-May-93

01 MODULE STRIP - DVB

AV. TAT 7.65

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
3043	5/1	5		
3093	5/1	7	6.0	
3078	21/12	10	7.3	DEC
3088	23/12	14	9.0	12.00
3063	13/2	10	9.2	
7081	15/2	7	8.8	
3100	9/2	6	8.4	FEB
247	26/2	9	8.5	8.00
8086	26/3	11	8.8	
7202M	5/4	7	8.6	
3082	6/4	7	8.5	
8010	6/4	18	9.3	
8406	7/4	9	9.2	
8012	9/4	21	10.1	
8108	13/4	5	9.7	
3048	23/4	3	9.3	
8408	24/4	11	9.4	
8426	24/4	8	9.3	APR
8402	24/4	9	9.3	9.80
3052	5/5	11	9.4	
8401	6/5	10	9.4	
3011M	11/5	6	9.3	
7219	13/5	5	9.1	
7203	20/5	6	9.0	
8051	21/5	6	8.8	
3098M	19/5	7	8.8	
7206	20/5	6	8.7	
8051	26/5	5	8.5	MAY
7234	26/5	2	8.3	6.40
7228M	3/6	10	8.4	
3021	7/6	9	8.4	
8021	17/6	7	8.3	
3028	21/6	5	8.2	
3076M	22/6	5	8.1	
3032	26/6	5	8.1	JUN

02 MODULE STRIP - DVB

AV. TAT 9.83

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
482	15/1	7		
3095	8/1	5	6.0	JAN
3076	6/1	12	8.0	8.00
7033	17/2	11	8.8	
3075	12/2	9	8.8	
3107	11/2	9	8.8	
3064	3/2	5	8.3	
7234	3/2	5	7.9	
7796	2/2	5	7.6	
7201	23/2	14	8.2	FEB
TZ247	26/2	7	8.1	8.13
8088	12/3	11	8.3	MAR
7201	23/3	14	8.8	12.50
3059	6/4	11	8.9	
483	9/4	5	8.7	
8406	13/4	3	8.3	
7034	19/4	10	8.4	
8427	22/4	14	8.7	
8402	26/4	11	8.8	APR
7239	29/4	6	8.7	8.57
3006	5/5	7	8.6	
8401	13/5	14	8.9	MAY
8407	20/5	15	9.1	12.00
8051	2/6	12	9.3	
611	18/6	18	9.6	
7247	16/6	13	9.7	
3024	16/6	9	9.7	
3077	18/6	9	9.7	
8023	22/6	11	9.7	
7019	28/6	14	9.9	
3098	22/6	8	9.8	JUN
7038	28/6	11	9.8	11.67
7780	2/7	14	10.0	
3018	6/7	17	10.2	
7205	12/7	22	10.5	

03 MODULE STRIP - DVB

AV. TAT 8.83

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
572	16/1	7		
3076	13/1	8	7.5	JAN
3078	4/1	9	8.0	8.00
3084	8/2	10	8.5	
3063	3/2	7	8.2	FEB
7001	2/2	7	8.0	8.00
TZ469	5/3	12	8.6	
8086	13/3	12	9.0	MAR
7207	25/3	13	9.4	12.33
8401	9/4	10	9.5	
8126	13/4	4	9.0	
7035	20/4	5	8.7	
8427	29/4	10	8.8	APR
8402	27/4	11	8.9	8.00
8407	13/5	14	9.3	MAY
7029	20/5	6	9.1	10.00
3047	16/6	9	9.1	
7246	20/6	11	9.2	
3044	23/6	9	9.2	JUN
3032	28/6	10	9.2	9.75
8023	1/7	9	9.2	
7026	15/7	3	8.9	
8414	26/7	5	8.7	
7039	5/7	13	8.9	JUL
8160	27/7	13	9.1	8.50
8179	16/8	8	9.0	AUG
3093	18/8	5	8.9	6.50
8107	16/9	12	9.0	
7041	28/9	12	9.1	
7766	29/9	11	9.2	SEP
8083	27/9	14	9.3	12.25
8144	22/10	5	9.2	OCT
8031	29/10	4	9.0	5.33
8103	27/10	7	9.0	
7245	29/11	16	9.2	NOV

DATE 06–May–93

01 MODULE STRIP - DVB

AV.TAT 7.65

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
12008	29/6	11	8.1	8.92
8162	13/7	6	8.1	JUL
8414	21/7	6	8.0	6.00
8177	6/8	8	8.0	
M3025	11/8	8	8.0	
8179	16/8	7	8.0	AUG
7010	24/8	10	8.0	8.25
8109	8/9	12	8.1	SEP
7042	13/9	10	8.2	8.00
7104	3/10	8	8.2	
3097	30/9	6	8.1	
7307	30/9	4	8.0	
8083	5/10	9	8.1	
8407	7/10	5	8.0	
3027	13/10	8	8.0	
8103	22/10	4	7.9	
7038	19/10	6	7.9	OCT
8031	25/10	5	7.8	7.08
8080	01/11	4	7.8	
8047	11/11	6	7.7	
8083	13/11	3	7.6	
8079	18/11	6	7.6	
7238	12/11	4	7.6	
3057	26/11	3	7.5	NOV
3067	29/11	7	7.5	4.71
8074	3/12	11	7.5	
3049	2/12	3	7.5	
590	12/12	6	7.4	
7030	10/12	8	7.4	
8085	9/12	5	7.4	
8081	10/12	6	7.4	
3014	19/12	6	7.4	
8415	23/12	7	7.4	
7051	29/12	14	7.4	
3092	29/12	15	7.6	

02 MODULE STRIP - DVB

AV.TAT 9.83

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
8411	14/7	21	10.8	JUL
8162	30/7	17	11.0	18.17
8179	11/8	14	11.1	10.805
8181	12/8	9	11.0	
8414	10/8	20	11.2	AUG
8161	25/8	14	11.3	14.25
8109	14/9	14	11.4	
547	22/9	14	11.4	
7043	23/9	7	11.3	SEP
8077	28/9	8	11.2	10.75
7053	11/10	11	11.2	
7015	18/10	13	11.3	
8144	29/10	13	11.3	OCT
8105	29/10	10	11.3	11.75
7024	3/11	7	11.2	
7050	5/11	8	11.1	
8031	8/11	7	11.1	
8048	12/11	6	11.0	
8082	11/11	6	10.9	NOV
8074	30/11	7	10.8	6.83
7037	6/12	9	10.8	
8087	16/12	10	10.8	
8084	24/12	11	10.8	
8415	29/12	12	10.8	DEC
8111	31/12	9	10.8	10.20
8147	10/1	11	10.8	
8042	16/1	9	10.7	JAN
3092	22/1	11	10.7	10.33
8078	3/2	7	10.7	
8083	2/2	10	10.7	
8013	11/2	9	10.6	
8231	14/2	7	10.6	
8185	18/2	8	10.5	
8182	22/2	9	10.5	
8412	22/2	8	10.5	

03 MODULE STRIP - DVB

AV.TAT 8.83

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
8079	18/11	6	9.1	11.00
8085	13/12	6	9.0	
8081	20/12	10	9.0	DEC
8109	23/12	8	9.0	8.00
8146	5/1	8	9.0	
8039	14/1	7	8.9	
3091	22/1	11	9.0	
8406	28/1	9	9.0	JAN
3048	26/1	7	8.9	8.40
8077	3/2	10	9.0	
8013	9/2	13	9.0	
8183	13/2	9	9.0	
8142	17/2	8	9.0	
7017	23/2	9	9.0	FEB
3033	25/2	8	9.0	9.50
8026	6/3	7	9.0	
8404	11/3	10	9.0	
8049	13/3	11	9.0	
8133	22/3	9	9.0	
8113	25/3	10	9.0	
8082	29/3	6	9.0	MAR
8158	30/3	6	8.9	8.43
8080	2/4	6	8.9	
8115	13/4	8	8.9	
3085	12/4	6	8.8	
8135	21/4	12	8.9	APRIL
7233	28/4	8	8.9	8.00
8030	1/5	7	8.8	

DATE 06–May–93

01 MODULE STRIP - DVB

AV.TAT 7.65

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
8107	30/12	13	7.6	DEC
M8435	20/12	5	7.6	8.25
8145	2/1	13	7.7	
7018	2/1	13	7.7	
8042	16/1	6	7.7	
7035	12/1	7	7.7	
8008	19/1	5	7.7	
8405	22/1	5	7.6	
3090	19/1	8	7.6	
8229	28/1	10	7.7	JAN
8007	27/1	9	7.7	8.44
8013	2/2	6	7.7	
8183	9/2	8	7.7	
8025	11/2	7	7.7	
8412	24/2	6	7.6	
3040	16/2	12	7.7	
3056	21/2	9	7.7	FEB
3006	22/2	8	7.7	8.00
7227	8/3	7	7.7	
8026	10/3	6	7.7	
8404	9/3	7	7.7	
8050	10/3	8	7.7	
530	1/3	7	7.7	
M3028	18/3	5	7.6	
8427	17/3	6	7.6	
8230	20/3	6	7.6	
8133	28/3	7	7.6	
8112	24/3	9	7.6	MAR
M586	31/3	10	7.6	7.09
8096	1/4	6	7.6	
8082	4/4	8	7.6	
8156	6/4	8	7.6	
8079	5/4	8	7.6	
M7026	8/4	8	7.6	
8432	11/4	8	7.6	

02 MODULE STRIP - DVB

AV.TAT 9.83

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
7040	25/2	8	10.5	FEB
3089	26/2	9	10.4	8.33
8047	6/3	6	10.4	
8050	11/3	9	10.4	
642	8/3	13	10.4	
7031	13/3	7	10.3	
7029	16/3	8	10.3	
8404	17/3	7	10.3	
8026	18/3	6	10.2	
8233	23/3	9	10.2	
8134	25/3	9	10.2	
8114	28/3	7	10.1	MAR
8028	26/3	6	10.1	7.91
8085	1/4	10	10.1	
8160	8/4	11	10.1	
8154R	6/4	12	10.1	
8081	7/4	8	10.1	
8433R	9/4	8	10.1	
7018	15/4	11	10.1	
8116	13/4	7	10.1	
8112R	15/4	7	10.0	
3078	24/4	15	10.1	
8435R	18/4	6	10.0	
8432R	19/4	6	10.0	
8432R	19/4	6	9.9	
8010	28/4	9	9.9	
8025R	27/4	3	9.9	APRIL
8030	30/4	6	9.8	8.33

03 MODULE STRIP - DVB

AV.TAT 8.83

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER

DATE 06-May-93

01 MODULE STRIP - DVB				
AV.TAT	7.65			
MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
7044	13/4	5	7.6	
3084	14/4	6	7.6	
8009	16/4	4	7.6	
8114	18/4	5	7.6	
3096	19/4	9	7.6	
8434	19/4	4	7.5	
8073	20/4	4	7.5	
8431	21/4	7	7.5	
8435	26/4	5	7.5	
8443R	24/4	2	7.4	
8108R	26/4	3	7.4	
8030	28/4	4	7.4	APRIL
8406R	28/4	5	7.3	5.74

02 MODULE STRIP - DVB				
AV.TAT	9.83			
MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER

03 MODULE STRIP - DVB				
AV.TAT	8.83			
MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER

RB211 MODULE TAT FROM JANUARY 1993

DATE 06–May–93

04 MODULE STRIP - DVB

AV.TA' 9.95

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
7787	7/1	10		
3075	15/1	10	10.0	
3082	7/1	14	11.3	JAN
5005	12/1	7	10.3	10.25
7237	24/2	14	11.0	
8087	19/12	10	10.8	
3055	10/2	7	10.3	
448	8/2	9	10.1	
3055	8/2	6	9.7	
3071	8/2	10	9.7	
7046	2/2	10	9.7	
7800	3/2	7	9.5	FEB
7207	24/2	12	9.7	11.36
TZ387	5/3	12	9.9	MAR
7823	25/3	13	10.1	12.5
8009	5/4	17	10.5	
8011	9/4	14	10.7	
GF5068	6/4	8	10.6	
8195	19/4	14	10.7	
7061	23/4	14	10.9	
8423	27/4	11	10.9	
8402	26/4	13	11.0	APR
8109	24/4	9	10.9	12.50
3057	10/5	14	11.0	
8403	10/5	12	11.1	
7029M	7/5	15	11.2	
3073	10/5	13	11.3	
3060	26/5	16	11.5	MAY
8042	30/5	9	11.4	13.17
7249	12/6	11	11.4	
3027	16/6	10	11.3	
5089	11/6	8	11.2	
3008	20/6	9	11.2	
3014	23/6	7	11.0	JUN
7053	25/6	9	11.0	9.00

05 MODULE STRIP - DVB

AV.TA' 9.56

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
5448	8/1	7		
3083	11/1	7	7.0	JAN
5062	12/1	7	7.0	7.00
7930	17/2	8	7.3	
8086	12/2	7	7.2	
3064	4/2	10	7.7	
7788	10/2	12	8.3	
7805	2/3	8	8.3	FEB
7823	24/2	13	8.8	10.00
TZ549	5/3	11	9.0	MAR
7796	12/3	4	8.5	7.67
8010	5/4	17	9.3	
8407	5/4	20	10.1	
8110	19/4	14	10.4	
GF5065	9/4	9	10.3	
7858	23/4	15	10.6	
8423	26/4	10	10.5	
8427	26/4	7	10.3	APR
8401	29/4	20	10.8	14.00
3096	10/5	13	11.0	
7806	6/5	13	11.0	
3098	13/5	6	10.8	
8027	18/5	17	11.1	MAY
7826	17/5	9	11.0	11.60
8047	8/6	18	11.3	
3031	15/6	8	11.2	
3011	20/6	10	11.1	
7921	22/6	9	11.0	JUN
3033	29/6	11	11.0	11.20
7795	2/7	11	11.0	
8162	15/7	3	10.8	
8410	25/7	6	10.6	JUL
8023	21/7	6	10.5	6.50
5083	2/8	14	10.6	
GF5049	6/8	8	10.5	

06 STRIP - C/DET

AV.TA' 6.52

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
5448	8/1	4		
8086	12/1	4	4.0	
8013	8/1	5	4.3	JAN
3095	12/1	7	5.0	5.00
7201	8/2	5	5.0	
7777	2/2	4	4.8	FEB
3065	4/2	4	4.7	4.33
7041	1/4	3	4.5	
3048	21/4	5	4.6	
7793	23/4	8	4.9	
8402	23/4	10	5.4	APR
3023	28/4	4	5.3	6.00
7226	3/5	11	5.7	
3045	10/5	7	5.8	
3034	17/5	2	5.5	
8184	13/5	3	5.4	
7031	18/5	3	5.2	
8184	13/5	7	5.3	MAY
7031	18/5	3	5.2	5.14
8023	8/6	5	5.2	
3066	4/6	3	5.1	
3044	15/6	6	5.1	
611	18/6	8	5.3	
3035	16/6	2	5.1	
7027	18/6	3	5.0	
3059	2/7	4	5.0	
8108	5/7	4	5.0	
8434	25/6	3	4.9	
7246	28/6	4	4.9	
8023	8/6	5	4.9	
3066	4/6	3	4.8	
3044	15/6	6	4.8	
611	18/6	8	4.9	
3035	16/6	2	4.9	JUN
7027	18/6	3	4.8	4.25

DATE 06-May-93

04 MODULE STRIP - DVB					05 MODULE STRIP - DVB					06 STRIP - C/DET				
AV.TAT	9.95				AV.TAT	9.56				AV.TAT	4.92			
MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER	MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER	MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
7041	5/7	17	11.1		8179	3/8	7	10.4		3059	2/7	4	4.8	
7033	30/6	9	11.1		8165	18/8	12	10.5		8108	5/7	4	4.8	
7038	30/6	9	11.0		7920	19/8	17	10.6		8434	25/6	3	4.7	
8409	17/7	19	11.2		GF5039	13/8	8	10.6		7246	28/6	4	4.7	JUL
655	15/7	22	11.5		8181	12/8	8	10.5		8160	14/7	4	4.7	4.00
7038	30/6	9	11.4		7844	23/8	13	10.6	AUG	3088	6/8	7	4.7	
3032	10/7	18	11.6		7824	24/8	8	10.5	10.71	8414	8/8	5	4.7	
8023	13/7	20	11.8		8161	8/9	9	10.5		3088	6/8	7	4.8	
GF5039	9/7	15	11.9		623	16/9	13	10.5		7234	9/8	5	4.8	
8427	2/8	14	11.9		7794	25/9	6	10.4		7774	10/8	4	4.8	
8172	29/7	20	12.1		8402	24/9	14	10.5		7234	9/8	5	4.8	AUG
7252	4/8	13	12.1		8083	23/9	10	10.5		584	27/8	9	4.9	6.00
GF5057	31/7	15	12.2	JUL	7817	28/9	5	10.4	SEP	8107	15/9	9	5.0	
5088	28/7	14	12.2	17.78	8083	23/9	7	10.3	9.14	7227	15/9	6	5.0	SEP
GF5105	6/8	7	12.1		GF5220	6/10	12	10.3		7792	23/9	3	4.9	6.00
8412	10/8	14	12.1		7840	10/10	7	10.3		7220	8/10	3	4.9	
8182	18/8	14	12.2		8104	22/10	7	10.2		8401	17/10	11	5.0	
7093	12/8	10	12.1		8031	28/10	9	10.2	OCT	3039	19/10	7	5.1	
GF5053	18/8	8	12.1	AUG	7804	29/10	7	10.1	8.40	8103	22/10	3	5.0	OCT
8184	20/8	8	12.0	11.00	8079	4/11	8	10.1		8031	26/10	6	5.0	6.00
7204	9/9	10	11.9		8087	17/11	9	10.1		3089	3/11	5	5.0	
8164	7/9	12	11.9		7812	19/11	7	10.0	NOV	8143	4/11	3	5.0	
8108	15/9	12	11.9	SEP	8074	23/11	8	10.0	8.00	8079	8/11	4	5.0	
7217	29/9	6	11.8	10.00	8117	3/12	7	9.9		8074	25/11	8	5.0	NOV
7310	4/10	19	12.0		8081	9/12	10	9.9		7045	25/11	3	5.0	4.60
GF5085	5/10	11	12.0		8085	13/12	7	9.9		3079	10/12	4	5.0	
7038	13/10	11	11.9		8147	29/12	13	9.9	DEC	8087	14/12	6	5.0	
7054	14/10	8	11.9	OCT	8111	22/12	9	9.9	9.20	8081	19/12	6	5.0	
8047	29/10	7	11.8	11.2	8051	14/1	10	9.9		8109	21/12	6	5.0	DEC
8149	4/11	8	11.7		8039	18/1	11	9.9		8146	23/12	3	5.0	5.00
7248	16/11	7	11.7		3093	22/1	11	10.0		8224	2/1	5	5.0	
7035	11/11	6	11.6		8405	14/1	11	10.0		3082	15/1	2	5.0	
7241	10/11	9	11.5		8408	25/1	7	9.9	JAN	8128	13/1	5	5.0	JAN
7224	12/11	5	11.4		8103	26/1	6	9.9	9.33	8405	21/1	4	4.9	4.00
7248	16/11	7	11.4		8077	3/2	12	9.9		3094	15/1	5	4.9	

04 MODULE STRIP - DVB

AV.TAT 9.95

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
				NOV
8048	25/11	11	11.4	7.57
8104	1/12	8	11.3	
8082	8/12	12	11.3	
8031	8/12	7	11.3	
8255	15/12	11	11.3	
8080	22/11	11	11.3	
8075	23/12	8	11.2	DEC
8439	21/12	2	11.1	8.43
8117	7/1	10	11.1	
8438	13/1	7	11.1	
7798	19/1	17	11.1	
8152	21/1	7	11.1	
8110	19/1	11	11.1	
3096	21/1	10	11.1	
3094	31/1	12	11.1	JAN
7312	28/1	11	11.1	10.63
8039	4/2	13	11.1	
8404	7/2	14	11.1	
8415	7/2	13	11.1	
8086	10/2	8	11.1	
8417	13/2	10	11.1	
8420	16/2	9	11.1	
8078	20/2	9	11.1	
7026	18/2	9	11.0	
8442	25/2	11	11.0	
7022	23/2	8	11.0	FEB
7027	26/2	8	11.0	10.18
8189	1/3	10	11.0	
8404	3/3	15	11.0	
8013	6/3	7	11.0	
8026	8/3	8	10.9	
8185	9/3	8	10.9	
547	10/3	17	11.0	
8050	14/3	12	11.0	

05 MODULE STRIP - DVB

AV.TAT 9.56

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
8011	4/2	8	9.9	
8185	13/2	10	9.9	
8419	10/2	8	9.8	
8182	16/2	9	9.8	FEB
8412	20/2	11	9.9	9.67
8026	8/3	8	9.8	
8404	11/3	10	9.8	
8050	14/3	12	9.9	
3090	9/3	10	9.9	
8417	16/3	11	9.9	
8236	17/3	9	9.9	
8134	22/3	12	9.9	
8112	22/3	10	9.9	
8114R	26/3	4	9.8	
8155	27/3	6	9.8	MAR
8160	31/3	9	9.8	9.18
8082	5/4	12	9.8	
8080	6/4	11	9.8	
8432R	11/4	6	9.8	
7801R	20/4	14	9.8	
8116	15/4	7	9.8	
8178R	20/4	8	9.8	
3039	24/4	11	9.8	
8435R	20/4	6	9.7	
8434R	22/4	5	9.7	
8431R	22/4	7	9.7	
8444R	22/4	4	9.6	
8249	29/4	10	9.6	APRIL
8234R	26/4	5	9.6	8.15

06 STRIP - C/DET

AV.TAT 6.52

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
8077	7/2	11	5.0	
8296	9/2	10	5.1	
8412	17/2	14	5.2	FEB
7238	26/2	10	5.3	10.00
3075	1/3	12	5.4	
3041	4/3	19	5.6	
7220	8/3	13	5.6	
7219	8/3	12	5.7	
8047	11/3	9	5.8	
8026	15/3	9	5.8	
8404	17/3	9	5.9	
8133	21/3	9	5.9	
8112	22/3	9	5.9	MAR
8417	29/3	9	6.0	11.00
8161	7/4	12	6.0	
8096	8/4	11	6.1	
8080	14/4	14	6.2	
8114	18/4	12	6.3	
7202	26/4	16	6.4	
3029	25/4	14	6.4	APRIL
7203	28/4	13	6.5	13.14

HB211 MODULE TAT FROM JANUARY 1993

DATE 06-May-93

04 MODULE STRIP - DVB

AV.TAT 9.95

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER
8410	15/3	9	11.0	
8025	16/3	3	10.9	
5496	21/3	17	10.9	
8448	17/3	7	10.9	
8103	21/3	4	10.8	
8239	22/3	8	10.8	
8037	24/3	9	10.8	
8114	25/3	7	10.8	
8090	29/3	8	10.7	MAR
8111R	15/4	16	10.8	9.71
8159	1/4	5	10.7	
8098	4/4	10	10.7	
8081	6/4	10	10.7	
8432R	13/4	8	10.7	
7786R	14/4	7	10.7	
8116	20/4	9	10.7	
8028R	20/4	6	10.6	
8435R	21/4	8	10.6	
8434R	21/4	7	10.6	
8431R	21/4	4	10.5	
8444R	23/4	6	10.5	
8421	29/4	9	10.5	
7032	30/4	9	10.4	APRIL
8411R	26/4	3	10.4	7.80
8419R	2/5	5	10.3	

05 MODULE STRIP - DVB

AV.TAT 9.56

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER

06 STRIP - C/DET

AV.TAT 4.92

MODULE No.	COMPLETE DATE	TRT	RUNNING AVERAGE	MONTH AVER

Appendix 4

Copy of the base program used for 'what-if' analysis

```
ProModel model: MANSTRI1
*manning levels in the strip shop

FUNCTIONS AND DISTRIBUTIONS
---------------------------
D1
0,1:: 2.8,24:: 8.4,48:: 14,72:: 25.2,96:: 36.4,120:: 50.4,144:: 67.2,168::
D1
80,198:: 90,230:: 95,260:: 100,300::
D2
0,1:: 4,24:: 12,48:: 36,62:: 56,120:: 60,148:: 64,172:: 76,196:: 84,220::
D2
92,248:: 99,272:: 100,300::
D3
0,1:: 15,24:: 37,154:: 51,178:: 57,200:: 65,240:: 75,260:: 100,350::

ROUTING
                    Output Next      Condi-   Move
Part Location Operation (min)  part location  tion Qty  time (min)
---- -------- ---------------  ---- --------  ---- --- ----------
*This model represents the input business unit, with manpower additions
*to the strip shop
*
*
*JT9 from outside to pit and ds. inclusion of manpower
JT9  OUT    1::          JT9  PIT      0  1  0
        0           DOWN9 MAN2    0  3  0
JT9  PIT    1::          JT9A  DS      0  1  5::
                    JT9B  DS      0  1  5::
                    JT9C  DS      0  1  5::
                    JT9D  DS      0  1  5::
                    JT9E  DS      0  1  10::
                    JT9F  DS      0  1  5::
                    JT9G  DS      0  1  5::
                    JT9H  DS      0  1  5::
                    JT9J  DS      0  1  10::
                    JT9K  DS      0  1  5::
                    JT9L  DS      0  1  10::
                    JT9V  DS      0  1  10::
*
DOWN9 MAN2   40::           DOWN9 EXIT    0  3  0
*
*Modules to detail strip
*
JT9A  DS    0          AHR  Q2      0  20  0
                    AHR  Q1      ALT 0  0
                    AHR  Q3      ALT 0  0
AHR  Q1    0          AHR  MAN1    0  1  0
AHR  MAN1   1::          HR9A  H1     0  1  0
AHR  Q2    0          AHR  MAN2    0  1  0
AHR  MAN2   1::          HR9A  H1     0  1  0
AHR  Q3    0          AHR  MAN3    0  1  0
AHR  MAN3   1::          HR9A  H1     0  1  0
JT9B  DS    0          BHR  Q2      0  64  0
                    BHR  Q1      ALT 0  0
                    BHR  Q3      ALT 0  0
BHR  Q1    0          BHR  MAN1    0  1  0
BHR  MAN1   1::          HR9B  H1     0  1  0
BHR  Q2    0          BHR  MAN2    0  1  0
BHR  MAN2   1::          HR9B  H1     0  1  0
BHR  Q3    0          BHR  MAN3    0  1  0
BHR  MAN3   1::          HR9B  H1     0  1  0
JT9C  DS    0          CHR  Q2      0  16  0
                    CHR  Q1      ALT 0  0
                    CHR  Q3      ALT 0  0
CHR  Q1    0          CHR  MAN1    0  1  0
CHR  MAN1   1::          HR9C  H1     0  1  0
CHR  Q2    0          CHR  MAN2    0  1  0
CHR  MAN2   1::          HR9C  H1     0  1  0
CHR  Q3    0          CHR  MAN3    0  1  0
CHR  MAN3   1::          HR9C  H1     0  1  0
JT9D  DS    0          DHR  Q2      0  15  0
                    DHR  Q1      ALT 0  0
                    DHR  Q3      ALT 0  0
DHR  Q1    0          DHR  MAN1    0  1  0
DHR  MAN1   1::          HR9D  H1     0  1  0
```

```
DHR  Q2    0          DHR  MAN2    0  1  0
DHR  MAN2    1::          HR9D H1     0  1  0
DHR  Q3    0          DHR  MAN3    0  1  0
DHR  MAN3    1::          HR9D H1     0  1  0
JT9E DS    0          EHR  Q2     0  6  0
                  EHR  Q1     ALT 0  0
                  EHR  Q3     ALT 0  0
EHR  Q1    0          EHR  MAN1    0  1  0
EHR  MAN1    1::          HR9E H1     0  1  0
EHR  Q2    0          EHR  MAN2    0  1  0
EHR  MAN2    1::          HR9E H1     0  1  0
EHR  Q3    0          EHR  MAN3    0  1  0
EHR  MAN3    1::          HR9E H1     0  1  0
JT9F DS    0          FHR  Q2     0  12  0
                  FHR  Q1     ALT 0  0
                  FHR  Q3     ALT 0  0
FHR  Q1    0          FHR  MAN1    0  1  0
FHR  MAN1    1::          HR9F H1     0  1  0
FHR  Q2    0          FHR  MAN2    0  1  0
FHR  MAN2    1::          HR9F H1     0  1  0
FHR  Q3    0          FHR  MAN3    0  1  0
FHR  MAN3    1::          HR9F H1     0  1  0
JT9G DS    0          GHR  Q2     0  3  0
                  GHR  Q1     ALT 0  0
                  GHR  Q3     ALT 0  0
GHR  Q1    0          GHR  MAN1    0  1  0
GHR  MAN1    1::          HR9G H1     0  1  0
GHR  Q2    0          GHR  MAN2    0  1  0
GHR  MAN2    1::          HR9G H1     0  1  0
GHR  Q3    0          GHR  MAN3    0  1  0
GHR  MAN3    1::          HR9G H1     0  1  0
JT9H DS    0          HHR  Q2     0  1  0
                  HHR  Q1     ALT 0  0
                  HHR  Q3     ALT 0  0
HHR  Q1    0          HHR  MAN1    0  1  0
HHR  MAN1    1::          HR9H H1     0  1  0
HHR  Q2    0          HHR  MAN2    0  1  0
HHR  MAN2    1::          HR9H H1     0  1  0
HHR  Q3    0          HHR  MAN3    0  1  0
HHR  MAN3    1::          HR9H H1     0  1  0
JT9J DS    0          JHR  Q2     0  18  0
                  JHR  Q1     ALT 0  0
                  JHR  Q3     ALT 0  0
JHR  Q1    0          JHR  MAN1    0  1  0
JHR  MAN1    1::          HR9J H1     0  1  0
JHR  Q2    0          JHR  MAN2    0  1  0
JHR  MAN2    1::          HR9J H1     0  1  0
JHR  Q3    0          JHR  MAN3    0  1  0
JHR  MAN3    1::          HR9J H1     0  1  0
JT9K DS    0          KHR  Q2     0  12  0
                  KHR  Q1     ALT 0  0
                  KHR  Q3     ALT 0  0
KHR  Q1    0          KHR  MAN1    0  1  0
KHR  MAN1    1::          HR9K H1     0  1  0
KHR  Q2    0          KHR  MAN2    0  1  0
KHR  MAN2    1::          HR9K H1     0  1  0
KHR  Q3    0          KHR  MAN3    0  1  0
KHR  MAN3    1::          HR9K H1     0  1  0
JT9L DS    0          LHR  Q2     0  4  0
                  LHR  Q1     ALT 0  0
                  LHR  Q3     ALT 0  0
LHR  Q1    0          LHR  MAN1    0  1  0
LHR  MAN1    1::          HR9L H1     0  1  0
LHR  Q2    0          LHR  MAN2    0  1  0
LHR  MAN2    1::          HR9L H1     0  1  0
LHR  Q3    0          LHR  MAN3    0  1  0
LHR  MAN3    1::          HR9L H1     0  1  0
JT9V DS    0          VHR  Q2     0  4  0
                  VHR  Q1     ALT 0  0
                  VHR  Q3     ALT 0  0
VHR  Q1    0          VHR  MAN1    0  1  0
VHR  MAN1    1::          HR9V H1     0  1  0
VHR  Q2    0          VHR  MAN2    0  1  0
VHR  MAN2    1::          HR9V H1     0  1  0
VHR  Q3    0          VHR  MAN3    0  1  0
VHR  MAN3    1::          HR9V H1     0  1  0
```

```
*
*JT8 engine from pit to detail strip
*
JT8  OUT1    0            JT8  8PIT     0   1   0
                        DOWN8 MAN3     0   2   0
JT8  8PIT    0           JT8A  DS      0   1   1::
                         JT8B  DS      0   1   5::
                         JT8C  DS      0   1   5::
                         JT8D  DS      0   1   5::
                         JT8E  DS      0   1   2::
                         JT8F  DS      0   1   5::
                         JT8H  DS      0   1   2::
                         JT8J  DS      0   1   5::
                         JT8K  DS      0   1   5::
                         JT8L  DS      0   1   5::
                         JT8V  DS      0   1   2::
*
DOWN8 MAN3   20::           DOWN8 EXIT     0   2   0
*
*Modules to detail strip
*
JT8A DS      0           A8HR Q3      0  10  0
                                A8HR Q2      ALT 0   0
                         A8HR Q1      ALT 0   0
A8HR Q1      0           A8HR MAN1    0   1   0
A8HR MAN1    3::          8HRA H18     0   1   0
A8HR Q2      0           A8HR MAN2    0   1   0
A8HR MAN2    3::          8HRA H18     0   1   0
A8HR Q3      0           A8HR MAN3    0   1   0
A8HR MAN3    2::          8HRA H18     0   1   0
JT8B DS      0           B8HR Q3      0  10  0
                    B8HR Q2      ALT 0   0
                    B8HR Q1      ALT 0   0
B8HR Q1      0           B8HR MAN1    0   1   0
B8HR MAN1    3::          8HRB H18     0   1   0
B8HR Q2      0           B8HR MAN2    0   1   0
B8HR MAN2    3::          8HRB H18     0   1   0
B8HR Q3      0           B8HR MAN3    0   1   0
B8HR MAN3    2::          8HRB H18     0   1   0
JT8C DS      0           C8HR Q3      0   5   0
                    C8HR Q2      ALT 0   0
                    C8HR Q1      ALT 0   0
C8HR Q1      0           C8HR MAN1    0   1   0
C8HR MAN1    3::          8HRC H18     0   1   0
C8HR Q2      0           C8HR MAN2    0   1   0
C8HR MAN2    3::          8HRC H18     0   1   0
C8HR Q3      0           C8HR MAN3    0   1   0
C8HR MAN3    2::          8HRC H18     0   1   0
JT8D DS      0           8DHR Q3      0   7   0
                    8DHR Q2      ALT 0   0
                    8DHR Q1      ALT 0   0
8DHR Q1      0           8DHR MAN1    0   1   0
8DHR MAN1    3::          8HRD H18     0   1   0
8DHR Q2      0           8DHR MAN2    0   1   0
8DHR MAN2    3::          8HRD H18     0   1   0
8DHR Q3      0           8DHR MAN3    0   1   0
8DHR MAN3    2::          8HRD H18     0   1   0
JT8E DS      0           E8HR Q3      0   2   0
                    E8HR Q2      ALT 0   0
                    E8HR Q1      ALT 0   0
E8HR Q1      0           E8HR MAN1    0   1   0
E8HR MAN1    3::          8HRE H18     0   1   0
E8HR Q2      0           E8HR MAN2    0   1   0
E8HR MAN2    3::          8HRE H18     0   1   0
E8HR Q3      0           E8HR MAN3    0   1   0
E8HR MAN3    2::          8HRE H18     0   1   0
JT8F DS      0           8FHR Q3      0   8   0
                    8FHR Q2      ALT 0   0
                    8FHR Q1      ALT 0   0
8FHR Q1      0           8FHR MAN1    0   1   0
8FHR MAN1    3::          8HRF H18     0   1   0
8FHR Q2      0           8FHR MAN2    0   1   0
8FHR MAN2    3::          8HRF H18     0   1   0
8FHR Q3      0           8FHR MAN3    0   1   0
8FHR MAN3    2::          8HRF H18     0   1   0
JT8H DS      0           H8HR Q3      0   5   0
```

```
                    H8HR Q2      ALT 0  0
                    H8HR Q1      ALT 0  0
H8HR Q1     0           H8HR MAN1    0  1  0
H8HR MAN1   3::            8HRH H18    0  1  0
H8HR Q2     0           H8HR MAN2    0  1  0
H8HR MAN2   3::            8HRH H18    0  1  0
H8HR Q3     0           H8HR MAN3    0  1  0
H8HR MAN3   2::            8HRH H18    0  1  0
JT8J DS     0         J8HR Q3      0  8  0
                    J8HR Q2      ALT 0  0
                    J8HR Q1      ALT 0  0
J8HR Q1     0          J8HR MAN1    0  1  0
J8HR MAN1   3::           8HRJ H18    0  1  0
J8HR Q2     0          J8HR MAN2    0  1  0
J8HR MAN2   3::           8HRJ H18    0  1  0
J8HR Q3     0          J8HR MAN3    0  1  0
J8HR MAN3   2::           8HRJ H18    0  1  0
JT8K DS     0          K8HR Q3      0  5  0
                    K8HR Q2      ALT 0  0
                    K8HR Q1      ALT 0  0
K8HR Q1     0           K8HR MAN1    0  1  0
K8HR MAN1   3::            8HRK H18    0  1  0
K8HR Q2     0           K8HR MAN2    0  1  0
K8HR MAN2   3::            8HRK H18    0  1  0
K8HR Q3     0           K8HR MAN3    0  1  0
K8HR MAN3   2::            8HRK H18    0  1  0
JT8L DS     0          L8HR Q3      0  8  0
                    L8HR Q2      ALT 0  0
                    L8HR Q1      ALT 0  0
L8HR Q1     0           L8HR MAN1    0  1  0
L8HR MAN1   3::            8HRL H18    0  1  0
L8HR Q2     0           L8HR MAN2    0  1  0
L8HR MAN2   3::            8HRL H18    0  1  0
L8HR Q3     0           L8HR MAN3    0  1  0
L8HR MAN3   2::            8HRL H18    0  1  0
JT8V DS     0           8HR Q3      0 1  0
                    8HR Q2       ALT 0  0
                    8HR Q1       ALT 0  0
8HR Q1      0           8HR MAN1    0  1  0
8HR MAN1    3::            8HRV H18    0  1  0
8HR Q2      0           8HR MAN2    0  1  0
8HR MAN2    3::            8HRV H18    0  1  0
8HR Q3      0           8HR MAN3    0  1  0
8HR MAN3    2::            8HRV H18    0  1  0
*
*Olympus engine from pit to detail strip
*
OLY OUT2    0             OLY OPIT    0  1  0
                    DOWNO MAN1    0  3  0
OLY OPIT    0             O1 DS      0  1  5::
                    O2 DS      0  1  5::
                    O3 DS      0  1  5::
                    O4 DS      0  1  5::
                    O5 DS      0  1  5::
                    O61 DS     0  1  5::
                    O62 DS     0  1  5::
                    O7 DS      0  1  5::
                    O8 DS      0  1  5::
                    O9 DS      0  1  5::
                    O10 DS     0  1  5::
                    O11 DS     0  1  5::
                    O12 DS     0  1  5::
*
DOWNO MAN1   40::          DOWNO EXIT     0  3  0
*
*Modules to detail strip
*
O1 DS       0          1OHR Q1      0  7  0
                    1OHR Q2      ALT 0  0
                    1OHR Q3      ALT 0  0
1OHR Q1     0           1OHR MAN1    0  1  0
1OHR MAN1   3::            OHR1 H10    0  1  0
1OHR Q2     0           1OHR MAN2    0  1  0
1OHR MAN2   3::            OHR1 H10    0  1  0
1OHR Q3     0           1OHR MAN3    0  1  0
1OHR MAN3   2::            OHR1 H10    0  1  0
```

```
O2 DS 0        2OHR Q1     0 30 0
               2OHR Q2     ALT 0 0
               2OHR Q3     ALT 0 0
2OHR Q1 0          2OHR MAN1   0 1 0
2OHR MAN1 3::        OHR2 H10   0 1 0
2OHR Q2 0          2OHR MAN2   0 1 0
2OHR MAN2 3::        OHR2 H10   0 1 0
2OHR Q3 0          2OHR MAN3   0 1 0
2OHR MAN3 2::        OHR2 H10   0 1 0
O3 DS 0        3OHR Q1     0 15 0
               3OHR Q2     ALT 0 0
               3OHR Q3     ALT 0 0
3OHR Q1 0          3OHR MAN1   0 1 0
3OHR MAN1 3::        OHR3 H10   0 1 0
3OHR Q2 0          3OHR MAN2   0 1 0
3OHR MAN2 3::        OHR3 H10   0 1 0
3OHR Q3 0          3OHR MAN3   0 1 0
3OHR MAN3 2::        OHR3 H10   0 1 0
O4 DS 0        4OHR Q1     0 12 0
               4OHR Q2     ALT 0 0
               4OHR Q3     ALT 0 0
4OHR Q1 0          4OHR MAN1   0 1 0
4OHR MAN1 3::        OHR4 H10   0 1 0
4OHR Q2 0          4OHR MAN2   0 1 0
4OHR MAN2 3::        OHR4 H10   0 1 0
4OHR Q3 0          4OHR MAN3   0 1 0
4OHR MAN3 2::        OHR4 H10   0 1 0
O5 DS 0        5OHR Q1     0 12 0
               5OHR Q2     ALT 0 0
               5OHR Q3     ALT 0 0
5OHR Q1 0          5OHR MAN1   0 1 0
5OHR MAN1 3::        OHR5 H10   0 1 0
5OHR Q2 0          5OHR MAN2   0 1 0
5OHR MAN2 3::        OHR5 H10   0 1 0
5OHR Q3 0          5OHR MAN3   0 1 0
5OHR MAN3 2::        OHR5 H10   0 1 0
O61 DS 0       AOHR Q1     0 39 0
               AOHR Q2     ALT 0 0
               AOHR Q3     ALT 0 0
AOHR Q1 0          AOHR MAN1   0 1 0
AOHR MAN1 3::        OHR61 H10   0 1 0
AOHR Q2 0          AOHR MAN2   0 1 0
AOHR MAN2 3::        OHR61 H10   0 1 0
AOHR Q3 0          AOHR MAN3   0 1 0
AOHR MAN3 2::        OHR61 H10   0 1 0
O62 DS 0       BOHR Q1     0 20 0
               BOHR Q2     ALT 0 0
               BOHR Q3     ALT 0 0
BOHR Q1 0          BOHR MAN1   0 1 0
BOHR MAN1 3::        OHR62 H10   0 1 0
BOHR Q2 0          BOHR MAN2   0 1 0
BOHR MAN2 3::        OHR62 H10   0 1 0
BOHR Q3 0          BOHR MAN3   0 1 0
BOHR MAN3 2::        OHR62 H10   0 1 0
O7 DS 0        7OHR Q1     0 2 0
               7OHR Q2     ALT 0 0
               7OHR Q3     ALT 0 0
7OHR Q1 0          7OHR MAN1   0 1 0
7OHR MAN1 3::        OHR7 H10   0 1 0
7OHR Q2 0          7OHR MAN2   0 1 0
7OHR MAN2 3::        OHR7 H10   0 1 0
7OHR Q3 0          7OHR MAN3   0 1 0
7OHR MAN3 2::        OHR7 H10   0 1 0
O8 DS 0        8OHR Q1     0 4 0
               8OHR Q2     ALT 0 0
               8OHR Q3     ALT 0 0
8OHR Q1 0          8OHR MAN1   0 1 0
8OHR MAN1 3::        OHR8 H10   0 1 0
8OHR Q2 0          8OHR MAN2   0 1 0
8OHR MAN2 3::        OHR8 H10   0 1 0
8OHR Q3 0          8OHR MAN3   0 1 0
8OHR MAN3 2::        OHR8 H10   0 1 0
O9 DS 0        9OHR Q1     0 2 0
               9OHR Q2     ALT 0 0
               9OHR Q3     ALT 0 0
9OHR Q1 0          9OHR MAN1   0 1 0
```

```
9OHR MAN1   3::         OHR9 H10     0  1  0
9OHR Q2     0          9OHR MAN2     0  1  0
9OHR MAN2   3::         OHR9 H10     0  1  0
9OHR Q3     0          9OHR MAN3     0  1  0
9OHR MAN3   2::         OHR9 H10     0  1  0
O10 DS      0        XOHR Q1       0  3  0
                XOHR Q2       ALT 0  0
                XOHR Q3       ALT 0  0
XOHR Q1     0          XOHR MAN1     0  1  0
XOHR MAN1   3::         OHR10 H10    0  1  0
XOHR Q2     0          XOHR MAN2     0  1  0
XOHR MAN2   3::         OHR10 H10    0  1  0
XOHR Q3     0          XOHR MAN3     0  1  0
XOHR MAN3   2::         OHR10 H10    0  1  0
O11 DS      0        YOHR Q1       0  4  0
                YOHR Q2       ALT 0  0
                YOHR Q3       ALT 0  0
YOHR Q1     0          YOHR MAN1     0  1  0
YOHR MAN1   3::         OHR11 H10    0  1  0
YOHR Q2     0          YOHR MAN2     0  1  0
YOHR MAN2   3::         OHR11 H10    0  1  0
YOHR Q3     0          YOHR MAN3     0  1  0
YOHR MAN3   2::         OHR11 H10    0  1  0
O12 DS      0        ZOHR Q1       0  15  0
                ZOHR Q2       ALT 0  0
                ZOHR Q3       ALT 0  0
ZOHR Q1     0          ZOHR MAN1     0  1  0
ZOHR MAN1   3::         OHR12 H10    0  1  0
ZOHR Q2     0          ZOHR MAN2     0  1  0
ZOHR MAN2   3::         OHR12 H10    0  1  0
ZOHR Q3     0          ZOHR MAN3     0  1  0
ZOHR MAN3   2::         OHR12 H10    0  1  0
*
*JT9 worked hours accumulated into modules
*
HR9A H1     ACCUM 20     JT9A H1Q     0  1  0
HR9B H1     ACCUM 64     JT9B H1Q     0  1  0
HR9C H1     ACCUM 16     JT9C H1Q     0  1  0
HR9D H1     ACCUM 15     JT9D H1Q     0  1  0
HR9E H1     ACCUM 6      JT9E H1Q     0  1  0
HR9F H1     ACCUM 12     JT9F H1Q     0  1  0
HR9G H1     ACCUM 3      JT9G H1Q     0  1  0
HR9H H1     ACCUM 1      JT9H H1Q     0  1  0
HR9J H1     ACCUM 18     JT9J H1Q     0  1  0
HR9K H1     ACCUM 12     JT9K H1Q     0  1  0
HR9L H1     ACCUM 4      JT9L H1Q     0  1  0
HR9V H1     ACCUM 4      JT9V H1Q     0  1  0
*
*JT8 worked hours accumulated into modules
*
8HRA H18    ACCUM 10     8A   H1Q     0  1  0
8HRB H18    ACCUM 10     8B   H1Q     0  1  0
8HRC H18    ACCUM 5      8C   H1Q     0  1  0
8HRD H18    ACCUM 7      8D   H1Q     0  1  0
8HRE H18    ACCUM 2      8E   H1Q     0  1  0
8HRF H18    ACCUM 8      8F   H1Q     0  1  0
8HRH H18    ACCUM 5      8H   H1Q     0  1  0
8HRJ H18    ACCUM 8      8J   H1Q     0  1  0
8HRK H18    ACCUM 4      8K   H1Q     0  1  0
8HRL H18    ACCUM 8      8L   H1Q     0  1  0
8HRV H18    ACCUM 2      8V   H1Q     0  1  0
*
*Olympus worked hours accumulated into modules
*
OHR1 H10    ACCUM 7      O1   H1Q     0  1  0
OHR2 H10    ACCUM 30     O2   H1Q     0  1  0
OHR3 H10    ACCUM 15     O3   H1Q     0  1  0
OHR4 H10    ACCUM 12     O4   H1Q     0  1  0
OHR5 H10    ACCUM 12     O5   H1Q     0  1  0
OHR61 H10   ACCUM 39     O61  H1Q     0  1  0
OHR62 H10   ACCUM 20     O62  H1Q     0  1  0
OHR7 H10    ACCUM 2      O7   H1Q     0  1  0
OHR8 H10    ACCUM 4      O8   H1Q     0  1  0
OHR9 H10    ACCUM 2      O9   H1Q     0  1  0
OHR10 H10   ACCUM 3      O10  H1Q     0  1  0
OHR11 H10   ACCUM 4      O11  H1Q     0  1  0
```

```
OHR12 H10    ACCUM 15       O12  H1Q    0  1  0
*
*JT9
*the modules are held before cleaning
*
JT9A  H1Q   0          JT9A  CLEAN   0  1  0
JT9B  H1Q   0          JT9B  CLEAN   0  1  0
JT9C  H1Q   0          JT9C  CLEAN   0  1  0
JT9D  H1Q   0          JT9D  CLEAN   0  1  0
JT9E  H1Q   0          JT9E  CLEAN   0  1  0
JT9F  H1Q   0          JT9F  CLEAN   0  1  0
JT9G  H1Q   0          JT9G  CLEAN   0  1  0
JT9H  H1Q   0          JT9H  CLEAN   0  1  0
JT9J  H1Q   0          JT9J  CLEAN   0  1  0
JT9K  H1Q   0          JT9K  CLEAN   0  1  0
JT9L  H1Q   0          JT9L  CLEAN   0  1  0
JT9V  H1Q   0          JT9V  CLEAN   0  1  0
*
*modules for cleaning
*
JT9A  CLEAN  16::      JT9A  H2   0  1  0
JT9B  CLEAN  32::      JT9B  H2   0  1  0
JT9C  CLEAN  14::      JT9C  H2   0  1  0
JT9D  CLEAN  14::      JT9D  H2   0  1  0
JT9E  CLEAN  3::       JT9E  H2   0  1  0
JT9F  CLEAN  6::       JT9F  H2   0  1  0
JT9G  CLEAN  6::       JT9G  H2   0  1  0
JT9H  CLEAN  0         JT9H  H2   0  1  0
JT9J  CLEAN  19::      JT9J  H2   0  1  0
JT9K  CLEAN  8::       JT9K  H2   0  1  0
JT9L  CLEAN  10::      JT9L  H2   0  1  0
JT9V  CLEAN  8::       JT9V  H2   0  1  0
*
*modules held before crack detect
*
JT9A  H2   0          JT9A  CRACK   0  1  0
JT9B  H2   0          JT9B  CRACK   0  1  0
JT9C  H2   0          JT9C  CRACK   0  1  0
JT9D  H2   0          JT9D  CRACK   0  1  0
JT9E  H2   0          JT9E  CRACK   0  1  0
JT9F  H2   0          JT9F  CRACK   0  1  0
JT9G  H2   0          JT9G  CRACK   0  1  0
JT9H  H2   0          JT9H  CRACK   0  1  0
JT9J  H2   0          JT9J  CRACK   0  1  0
JT9K  H2   0          JT9K  CRACK   0  1  0
JT9L  H2   0          JT9L  CRACK   0  1  0
JT9V  H2   0          JT9V  CRACK   0  1  0
*
*modules go for crack detect
*
JT9A  CRACK  5::       JT9A  H3   0  1  0
JT9B  CRACK  14::      JT9B  H3   0  1  0
JT9C  CRACK  14::      JT9C  H3   0  1  0
JT9D  CRACK  6::       JT9D  H3   0  1  0
JT9E  CRACK  2::       JT9E  H3   0  1  0
JT9F  CRACK  0         JT9F  H3   0  1  0
JT9G  CRACK  2::       JT9G  H3   0  1  0
JT9H  CRACK  0         JT9H  H3   0  1  0
JT9J  CRACK  4::       JT9J  H3   0  1  0
JT9K  CRACK  6::       JT9K  H3   0  1  0
JT9L  CRACK  8::       JT9L  H3   0  1  0
JT9V  CRACK  3::       JT9V  H3   0  1  0
*
*modules held before dvb
*
JT9A  H3   0          JT9A  DV   0  1  0
JT9B  H3   0          JT9B  DV   0  1  0
JT9C  H3   0          JT9C  DV   0  1  0
JT9D  H3   0          JT9D  DV   0  1  0
JT9E  H3   0          JT9E  DV   0  1  0
JT9F  H3   0          JT9F  DV   0  1  0
JT9G  H3   0          JT9G  DV   0  1  0
JT9H  H3   0          JT9H  DV   0  1  0
JT9J  H3   0          JT9J  DV   0  1  0
JT9K  H3   0          JT9K  DV   0  1  0
JT9L  H3   0          JT9L  DV   0  1  0
```

```
JT9V  H3     0           JT9V  DV      0  1  0
*
*detail viewing
*
JT9A  DV     8::         JT9A  G9      0  1  0
JT9B  DV     18:30:      JT9B  G9      0  1  0
JT9C  DV     9::         JT9C  G9      0  1  0
JT9D  DV     7:30:       JT9D  G9      0  1  0
JT9E  DV     5::         JT9E  G9      0  1  0
JT9F  DV     10::        JT9F  G9      0  1  0
JT9G  DV     5::         JT9G  G9      0  1  0
JT9H  DV     0           JT9H  G9      0  1  0
JT9J  DV     10::        JT9J  G9      0  1  0
JT9K  DV     12::        JT9K  G9      0  1  0
JT9L  DV     6::         JT9L  G9      0  1  0
JT9V  DV     4::         JT9V  G9      0  1  0
        V12,-1
*
*
*
*
JT9A  G9     IF V11=0 THEN +2  JT9A  EXIT    0  1  0
        2000::
        0
JT9B  G9     IF V11=0 THEN +2  JT9B  EXIT    0  1  0
        2000::
        0
JT9C  G9     IF V11=0 THEN +2  JT9C  EXIT    0  1  0
        2000::
        0
JT9D  G9     IF V11=0 THEN +2  JT9D  EXIT    0  1  0
        2000::
        0
JT9E  G9     IF V11=0 THEN +2  JT9E  EXIT    0  1  0
        2000::
        0
JT9F  G9     IF V11=0 THEN +2  JT9F  EXIT    0  1  0
        2000::
        0
JT9G  G9     IF V11=0 THEN +2  JT9G  EXIT    0  1  0
        2000::
        0
JT9H  G9     IF V11=0 THEN +2  JT9H  EXIT    0  1  0
        2000::
        0
JT9J  G9     IF V11=0 THEN +2  JT9J  EXIT    0  1  0
        2000::
        0
JT9K  G9     IF V11=0 THEN +2  JT9K  EXIT    0  1  0
        2000::
        0
JT9L  G9     IF V11=0 THEN +2  JT9L  EXIT    0  1  0
        2000::
        0
JT9V  G9     IF V11=0 THEN +2  JT9V  EXIT    0  1  0
        2000::
        0
*OLYMPUS
*
*Joins all the modules together
*the modules are held before cleaning
O1   H1Q    0           O1   CLEAN    0  1  0
O2   H1Q    0           O2   CLEAN    0  1  0
O3   H1Q    0           O3   CLEAN    0  1  0
O4   H1Q    0           O4   CLEAN    0  1  0
O5   H1Q    0           O5   CLEAN    0  1  0
O61  H1Q    0           O61  CLEAN    0  1  0
O62  H1Q    0           O62  CLEAN    0  1  0
O7   H1Q    0           O7   CLEAN    0  1  0
O8   H1Q    0           O8   CLEAN    0  1  0
O9   H1Q    0           O9   CLEAN    0  1  0
O10  H1Q    0           O10  CLEAN    0  1  0
O11  H1Q    0           O11  CLEAN    0  1  0
O12  H1Q    0           O12  CLEAN    0  1  0
*modules for cleaning
O1   CLEAN  3::         O1   H2       0  1  0
```

```
O2   CLEAN   24::        O2   H2      0  1  0
O3   CLEAN   8::         O3   H2      0  1  0
O4   CLEAN   6::         O4   H2      0  1  0
O5   CLEAN   6::         O5   H2      0  1  0
O61  CLEAN   66::        O61  H2      0  1  0
O62  CLEAN   12::        O62  H2      0  1  0
O7   CLEAN   10::        O7   H2      0  1  0
O8   CLEAN   2::         O8   H2      0  1  0
O9   CLEAN   12::        O9   H2      0  1  0
O10  CLEAN   4::         O10  H2      0  1  0
O11  CLEAN   12::        O11  H2      0  1  0
O12  CLEAN   6::         O12  H2      0  1  0
*modules held before crack detect
O1   H2   0         O1   CRACK   0  1  0
O2   H2   0         O2   CRACK   0  1  0
O3   H2   0         O3   CRACK   0  1  0
O4   H2   0         O4   CRACK   0  1  0
O5   H2   0         O5   CRACK   0  1  0
O61  H2   0         O61  CRACK   0  1  0
O62  H2   0         O62  CRACK   0  1  0
O7   H2   0         O7   CRACK   0  1  0
O8   H2   0         O8   CRACK   0  1  0
O9   H2   0         O9   CRACK   0  1  0
O10  H2   0         O10  CRACK   0  1  0
O11  H2   0         O11  CRACK   0  1  0
O12  H2   0         O12  CRACK   0  1  0
*modules go for crack detect
O1   CRACK   3::         O1   H3      0  1  0
O2   CRACK   14::        O2   H3      0  1  0
O3   CRACK   4::         O3   H3      0  1  0
O4   CRACK   4::         O4   H3      0  1  0
O5   CRACK   4::         O5   H3      0  1  0
O61  CRACK   14::        O61  H3      0  1  0
O62  CRACK   4::         O62  H3      0  1  0
O7   CRACK   1:30:       O7   H3      0  1  0
O8   CRACK   0           O8   H3      0  1  0
O9   CRACK   2::         O9   H3      0  1  0
O10  CRACK   0           O10  H3      0  1  0
O11  CRACK   2::         O11  H3      0  1  0
O12  CRACK   3::         O12  H3      0  1  0
*modules held before dvb
O1   H3   0         O1   DV    0  1  0
O2   H3   0         O2   DV    0  1  0
O3   H3   0         O3   DV    0  1  0
O4   H3   0         O4   DV    0  1  0
O5   H3   0         O5   DV    0  1  0
O61  H3   0         O61  DV    0  1  0
O62  H3   0         O62  DV    0  1  0
O7   H3   0         O7   DV    0  1  0
O8   H3   0         O8   DV    0  1  0
O9   H3   0         O9   DV    0  1  0
O10  H3   0         O10  DV    0  1  0
O11  H3   0         O11  DV    0  1  0
O12  H3   0         O12  DV    0  1  0
*detail viewing
O1   DV   4::       O1   GO    0  1  0
O2   DV   9::       O2   GO    0  1  0
O3   DV   11::      O3   GO    0  1  0
O4   DV   10::      O4   GO    0  1  0
O5   DV   10::      O5   GO    0  1  0
O61  DV   11:30:    O61  GO    0  1  0
O62  DV   15::      O62  GO    0  1  0
O7   DV   2::       O7   GO    0  1  0
O8   DV   2::       O8   GO    0  1  0
O9   DV   4::       O9   GO    0  1  0
O10  DV   3::       O10  GO    0  1  0
O11  DV   4::       O11  GO    0  1  0
O12  DV   15::      O12  GO    0  1  0
        V14,-1
*
O1   GO    IF V11=0 THEN +2  O1   EXIT    0  1  0
       2000::
       0
O2   GO    IF V11=0 THEN +2  O2   EXIT    0  1  0
       2000::
       0
```

```
O3  GO    IF V11=0 THEN +2  O3   EXIT    0  1  0
      2000::
      0
O4  GO    IF V11=0 THEN +2  O4   EXIT    0  1  0
      2000::
      0
O5  GO    IF V11=0 THEN +2  O5   EXIT    0  1  0
      2000::
      0
O61 GO    IF V11=0 THEN +2  O61  EXIT    0  1  0
      2000::
      0
O62 GO    IF V11=0 THEN +2  O62  EXIT    0  1  0
      2000::
      0
O7  GO    IF V11=0 THEN +2  O7   EXIT    0  1  0
      2000::
      0
O8  GO    IF V11=0 THEN +2  O8   EXIT    0  1  0
      2000::
      0
O9  GO    IF V11=0 THEN +2  O9   EXIT    0  1  0
      2000::
      0
O10 GO    IF V11=0 THEN +2  O10  EXIT    0  1  0
      2000::
      0
O11 GO    IF V11=0 THEN +2  O11  EXIT    0  1  0
      2000::
      0
O12 GO    IF V11=0 THEN +2  O12  EXIT    0  1  0
      2000::
      0
*JT8
*
*the modules are held before cleaning
8A  H1Q   0        8A  CLEAN   0  1  0
8B  H1Q   0        8B  CLEAN   0  1  0
8C  H1Q   0        8C  CLEAN   0  1  0
8D  H1Q   0        8D  CLEAN   0  1  0
8E  H1Q   0        8E  CLEAN   0  1  0
8F  H1Q   0        8F  CLEAN   0  1  0
8H  H1Q   0        8H  CLEAN   0  1  0
8J  H1Q   0        8J  CLEAN   0  1  0
8K  H1Q   0        8K  CLEAN   0  1  0
8L  H1Q   0        8L  CLEAN   0  1  0
8V  H1Q   0        8V  CLEAN   0  1  0
*modules for cleaning
8A  CLEAN  3::      8A  H2    0  1  0
8B  CLEAN  4::      8B  H2    0  1  0
8C  CLEAN  1::      8C  H2    0  1  0
8D  CLEAN  2::      8D  H2    0  1  0
8E  CLEAN  1::      8E  H2    0  1  0
8F  CLEAN  2::      8F  H2    0  1  0
8H  CLEAN  2::      8H  H2    0  1  0
8J  CLEAN  4::      8J  H2    0  1  0
8K  CLEAN  3::      8K  H2    0  1  0
8L  CLEAN  2::      8L  H2    0  1  0
8V  CLEAN  1::      8V  H2    0  1  0
*modules held before crack detect
8A  H2    0        8A  CRACK   0  1  0
8B  H2    0        8B  CRACK   0  1  0
8C  H2    0        8C  CRACK   0  1  0
8D  H2    0        8D  CRACK   0  1  0
8E  H2    0        8E  CRACK   0  1  0
8F  H2    0        8F  CRACK   0  1  0
8H  H2    0        8H  CRACK   0  1  0
8J  H2    0        8J  CRACK   0  1  0
8K  H2    0        8K  CRACK   0  1  0
8L  H2    0        8L  CRACK   0  1  0
8V  H2    0        8V  CRACK   0  1  0
*modules go for crack detect
8A  CRACK  2::      8A  H3    0  1  0
8B  CRACK  3::      8B  H3    0  1  0
8C  CRACK  1::      8C  H3    0  1  0
8D  CRACK  1::      8D  H3    0  1  0
```

```
8E  CRACK  1::        8E  H3    0  1  0
8F  CRACK  2::        8F  H3    0  1  0
8H  CRACK  1::        8H  H3    0  1  0
8J  CRACK  1::        8J  H3    0  1  0
8K  CRACK  2::        8K  H3    0  1  0
8L  CRACK  2::        8L  H3    0  1  0
8V  CRACK  1::        8V  H3    0  1  0
*modules held before dvb
8A  H3   0        8A  DV    0  1  0
8B  H3   0        8B  DV    0  1  0
8C  H3   0        8C  DV    0  1  0
8D  H3   0        8D  DV    0  1  0
8E  H3   0        8E  DV    0  1  0
8F  H3   0        8F  DV    0  1  0
8H  H3   0        8H  DV    0  1  0
8J  H3   0        8J  DV    0  1  0
8K  H3   0        8K  DV    0  1  0
8L  H3   0        8L  DV    0  1  0
8V  H3   0        8V  DV    0  1  0
*detail viewing
8A  DV   16::      8A  G8    0  1  0
8B  DV   12::      8B  G8    0  1  0
8C  DV   8::       8C  G8    0  1  0
8D  DV   15::      8D  G8    0  1  0
8E  DV   18::      8E  G8    0  1  0
8F  DV   20::      8F  G8    0  1  0
8H  DV   12::      8H  G8    0  1  0
8J  DV   10::      8J  G8    0  1  0
8K  DV   14::      8K  G8    0  1  0
8L  DV   8::       8L  G8    0  1  0
8V  DV   14::      8V  G8    0  1  0
        V13,-1
*
8A  G8   IF V11=0 THEN +2  8A  EXIT   0  1  0
        2000::
        0
8B  G8   IF V11=0 THEN +2  8B  EXIT   0  1  0
        2000::
        0
8C  G8   IF V11=0 THEN +2  8C  EXIT   0  1  0
        2000::
        0
8D  G8   IF V11=0 THEN +2  8D  EXIT   0  1  0
        2000::
        0
8E  G8   IF V11=0 THEN +2  8E  EXIT   0  1  0
        2000::
        0
8F  G8   IF V11=0 THEN +2  8F  EXIT   0  1  0
        2000::
        0
8H  G8   IF V11=0 THEN +2  8H  EXIT   0  1  0
        2000::
        0
8J  G8   IF V11=0 THEN +2  8J  EXIT   0  1  0
        2000::
        0
8K  G8   IF V11=0 THEN +2  8K  EXIT   0  1  0
        2000::
        0
8L  G8   IF V11=0 THEN +2  8L  EXIT   0  1  0
        2000::
        0
8V  G8   IF V11=0 THEN +2  8V  EXIT   0  1  0
        2000::
        0
*
*RB211 modules
RB01 ROUT  0       RB01 RPIT   0  1  0
RB02 ROUT  0       RB02 RPIT   0  1  0
RB03 ROUT  0       RB03 RPIT   0  1  0
RB04 ROUT  0       RB04 RPIT   0  1  0
RB05 ROUT  0       RB05 RPIT   0  1  0
RB06 ROUT  0       RB06 RPIT   0  1  0
*
RB01 RPIT  0       RB01 DS     0  1  3::
```

```
                RBDU1 MAN1    0  3  0
RB02 RPIT   0       RB02 DS     0  1  3::
                RBDU2 MAN1    0  3  0
RB03 RPIT   0       RB03 DS     0  1  3::
                RBDU3 MAN1    0  3  0
RB04 RPIT   0       RB04 DS     0  1  3::
                RBDU4 MAN1    0  3  0
RB05 RPIT   0       RB05 DS     0  1  3::
                RBDU5 MAN1    0  3  0
RB06 RPIT   0       RB06 DS     0  1  3::
                RBDU6 MAN1    0  3  0
*
RBDU1 MAN1   3::        RBDU1 EXIT    0  3  0
RBDU2 MAN1   3::        RBDU2 EXIT    0  3  0
RBDU3 MAN1   3::        RBDU3 EXIT    0  3  0
RBDU4 MAN1   3::        RBDU4 EXIT    0  3  0
RBDU5 MAN1   3::        RBDU5 EXIT    0  3  0
RBDU6 MAN1   3::        RBDU6 EXIT    0  3  0
*
*Modules to detail strip
*
RB01 DS    0        RHR1 Q1     0  3  0
                RHR1 Q2      ALT 0  0
                RHR1 Q3      ALT 0  0
RHR1 Q1    0        RHR1 MAN1    0  1  0
RHR1 MAN1   3::         RHR1 HRB211   0  1  0
RHR1 Q2    0        RHR1 MAN2    0  1  0
RHR1 MAN2   3::         RHR1 HRB211   0  1  0
RHR1 Q3    0        RHR1 MAN3    0  1  0
RHR1 MAN3   2::         RHR1 HRB211   0  1  0
RB02 DS    0        RHR2 Q1     0  45  0
                RHR2 Q2      ALT 0  0
                RHR2 Q3      ALT 0  0
RHR2 Q1    0        RHR2 MAN1    0  1  0
RHR2 MAN1   3::         RHR2 HRB211   0  1  0
RHR2 Q2    0        RHR2 MAN2    0  1  0
RHR2 MAN2   3::         RHR2 HRB211   0  1  0
RHR2 Q3    0        RHR2 MAN3    0  1  0
RHR2 MAN3   2::         RHR2 HRB211   0  1  0
RB03 DS    0        RHR3 Q1     0  12  0
                RHR3 Q2      ALT 0  0
                RHR3 Q3      ALT 0  0
RHR3 Q1    0        RHR3 MAN1    0  1  0
RHR3 MAN1   3::         RHR3 HRB211   0  1  0
RHR3 Q2    0        RHR3 MAN2    0  1  0
RHR3 MAN2   3::         RHR3 HRB211   0  1  0
RHR3 Q3    0        RHR3 MAN3    0  1  0
RHR3 MAN3   2::         RHR3 HRB211   0  1  0
RB04 DS    0        RHR4 Q1     0  57  0
                RHR4 Q2      ALT 0  0
                RHR4 Q3      ALT 0  0
RHR4 Q1    0        RHR4 MAN1    0  1  0
RHR4 MAN1   3::         RHR4 HRB211   0  1  0
RHR4 Q2    0        RHR4 MAN2    0  1  0
RHR4 MAN2   3::         RHR4 HRB211   0  1  0
RHR4 Q3    0        RHR4 MAN3    0  1  0
RHR4 MAN3   2::         RHR4 HRB211   0  1  0
RB05 DS    0        RHR5 Q1     0  53  0
                RHR5 Q2      ALT 0  0
                RHR5 Q3      ALT 0  0
RHR5 Q1    0        RHR5 MAN1    0  1  0
RHR5 MAN1   3::         RHR5 HRB211   0  1  0
RHR5 Q2    0        RHR5 MAN2    0  1  0
RHR5 MAN2   3::         RHR5 HRB211   0  1  0
RHR5 Q3    0        RHR5 MAN3    0  1  0
RHR5 MAN3   2::         RHR5 HRB211   0  1  0
RB06 DS    0        RHR6 Q1     0  12  0
                RHR6 Q2      ALT 0  0
                RHR6 Q3      ALT 0  0
RHR6 Q1    0        RHR6 MAN1    0  1  0
RHR6 MAN1   3::         RHR6 HRB211   0  1  0
RHR6 Q2    0        RHR6 MAN2    0  1  0
RHR6 MAN2   3::         RHR6 HRB211   0  1  0
RHR6 Q3    0        RHR6 MAN3    0  1  0
RHR6 MAN3   2::         RHR6 HRB211   0  1  0
*
```

```
RHR1 HRB211  ACCUM 3       RB01 H1Q    0  1  0
RHR2 HRB211  ACCUM 45      RB02 H1Q    0  1  0
RHR3 HRB211  ACCUM 12      RB03 H1Q    0  1  0
RHR4 HRB211  ACCUM 57      RB04 H1Q    0  1  0
RHR5 HRB211  ACCUM 53      RB05 H1Q    0  1  0
RHR6 HRB211  ACCUM 12      RB06 H1Q    0  1  0
*
*the modules are held before cleaning
RB01 H1Q   0         RB01 CLEAN   0  1  0
RB02 H1Q   0         RB02 CLEAN   0  1  0
RB03 H1Q   0         RB03 CLEAN   0  1  0
RB04 H1Q   0         RB04 CLEAN   0  1  0
RB05 H1Q   0         RB05 CLEAN   0  1  0
RB06 H1Q   0         RB06 CLEAN   0  1  0
*modules for cleaning
RB01 CLEAN  6::        RB01 H2    0  1  0
RB02 CLEAN  34::       RB02 H2    0  1  0
RB03 CLEAN  8::        RB03 H2    0  1  0
RB04 CLEAN  33::       RB04 H2    0  1  0
RB05 CLEAN  52::       RB05 H2    0  1  0
RB06 CLEAN  6::        RB06 H2    0  1  0
*modules held before crack detect
RB01 H2    0         RB01 CRACK   0  1  0
RB02 H2    0         RB02 CRACK   0  1  0
RB03 H2    0         RB03 CRACK   0  1  0
RB04 H2    0         RB04 CRACK   0  1  0
RB05 H2    0         RB05 CRACK   0  1  0
RB06 H2    0         RB06 CRACK   0  1  0
*modules go for crack detect
RB01 CRACK  2::        RB01 H3    0  1  0
RB02 CRACK  16::       RB02 H3    0  1  0
RB03 CRACK  6::        RB03 H3    0  1  0
RB04 CRACK  17::       RB04 H3    0  1  0
RB05 CRACK  15::       RB05 H3    0  1  0
RB06 CRACK  3::        RB06 H3    0  1  0
*modules held before dvb
RB01 H3    0         RB01 DV    0  1  0
RB02 H3    0         RB02 DV    0  1  0
RB03 H3    0         RB03 DV    0  1  0
RB04 H3    0         RB04 DV    0  1  0
RB05 H3    0         RB05 DV    0  1  0
RB06 H3    0         RB06 DV    0  1  0
*detail viewing
RB01 DV    5::        RB01 RBG    0  1  0
       V15,-1
RB02 DV    8:30:      RB02 RBG    0  1  0
       V16,-1
RB03 DV    12::       RB03 RBG    0  1  0
       V17,-1
RB04 DV    11::       RB04 RBG    0  1  0
       V18,-1
RB05 DV    11:30:     RB05 RBG    0  1  0
       V19,-1
RB06 DV    10::       RB06 RBG    0  1  0
       V20,-1
*
RB01 RBG   IF V11=0 THEN +2  RB01 EXIT    0  1  0
       2000::
       0
RB02 RBG   IF V11=0 THEN +2  RB02 EXIT    0  1  0
       2000::
       0
RB03 RBG   IF V11=0 THEN +2  RB03 EXIT    0  1  0
       2000::
       0
RB04 RBG   IF V11=0 THEN +2  RB04 EXIT    0  1  0
       2000::
       0
RB05 RBG   IF V11=0 THEN +2  RB05 EXIT    0  1  0
       2000::
       0
RB06 RBG   IF V11=0 THEN +2  RB06 EXIT    0  1  0
       2000::
       0
*
*CLOCK ON SCREEN
```

```
*
TIME DUMMY  V11=0         TIME EXIT   0  1  0
        V10=0
        V9=0
        1
        IF V9=59,+3
        V9,+1
        -3
        V10,+1
        IF V10=24,+2
        -7
        V11,+1
        V10=00
        -10
*
*END OF CLOCK FUNCTION
*

PART SCHEDULING
              Qty per  No. of   Start   Arrival
 Part  Location  arrival arrivals (min)  frequency (min)
 ----- -------- ------- -------- -----  --------------
JT9   OUT      1     100    1      D1
OLY   OUT2     1     100    280::  D2
JT8   OUT1     1     100    100::  D3
TIME  DUMMY    1     1      240::  0
RB01  ROUT     1     100    0      72::
RB02  ROUT     1     100    0      74::
RB03  ROUT     1     100    0      76::
RB04  ROUT     1     100    0      78::
RB05  ROUT     1     100    0      80::
RB06  ROUT     1     100    0      82::

DOWNTIMES
           Freq(min,cyc)  Duration     Start or     Maintenance
Resource  Basis or Setup part (min)     Lead part  Qty  resource
-------- ----- ------------ ----------- -------- --- -------
DV,*     SHIFT 24::     8::       23::    1  HOME*
DV,*     SHIFT 24::     8::       23::    1  HOME*
DV,*     SHIFT 24::     8::       23::    1  HOME*
DV,*     SHIFT 24::     8::       23::    1  HOME*
DV,*     SHIFT 24::     8::       23::    1  HOME*
DV,*     SHIFT 24::     8::       23::    1  HOME*
CLEAN,*  SHIFT 24::     8::       23::    1  HOME*

CAPACITIES
Resource Qty  Resource Qty  Resource Qty  Resource Qty  Resource Qty
-------- ---- -------- ---- -------- ---- -------- ---- -------- ----
8PIT    1   DS      3    H1     1000  H10    1000  H18    1000
H1Q     10  HRB211  6000 MAN1   &3    MAN2   &3    MAN3   &2
OPIT    1   OUT     1000 PIT    1     Q1     21    Q2     21
Q3      14  CLEAN   2    CRACK  1     DUMMY  1     DV     6
G8      40  G9      40   GO     40    H2     5     H3     5
HOME*   10  OUT1    1000 OUT2   1000  RBG    40    ROUT   1000
RPIT    100

SIMULATION PARAMETERS                 GRAPHIC OPTIONS
Run   Startup Rept Resource          Graph Max Max Scr Fig Icon
(hrs) (hrs)  code to track  Seed     mode  row col clr clr file
----- ------ ---- -------- ----     ----- --- --- --- --- ----
1000  0      2    0        0        3    100 200 B  W   PM.LIB

STATIC SYMBOLS
ID     Sym Clr Row Col ID     Sym Clr Row Col ID     Sym Clr Row Col
-------- --- --- --- --- -------- --- --- --- --- -------- --- --- --- ---
PIT    2   W   10  21  V13    0   0   1   28  V14    0   0   1   25
V15    0   0   5   33  V16    0   0   7   33  V17    0   0   9   33
V18    0   0   11  33  V19    0   0   13  33  V20    0   0   15  33
V10    0   0   35  30  V12    0   0   1   21  DS     3R  W   16  21
Q1     WB  W   19  16  MAN1   8R  Y   22  12  Q2     WB  W   19  22
MAN2   8R  R   22  20  Q3     WB  W   19  28  MAN3   8R  M   22  28
8PIT   2   W   10  27  OPIT   2   W   10  24  H1     WB  W   5   35
H18    WB  W   8   35  RBG    XL  W   44  45  G9     XL  W   48  45
V11    0   0   39  30  CLEAN  1R  W   12  63  H2     XD  W   17  64
CRACK  3D  W   28  64  H3     XD  W   35  64  DV     5R  W   43  57
V10    0   0   35  30  V9     0   0   35  33  GO     XL  W   46  45
```

```
G8     XL W   42 45 DUMMY  1 W   35 39 HOME*  2 W   39 39
HOME   1 W   21  4 H1Q    XR W   12 48 OUT    WB W   10  3
OUT1   WB W   13  3 OUT2   WB W   16  3 ROUT   WB W    7  3
RPIT   2 W   10 30 HRB211 WB W   14 35 H10    WB W   11 35
```

DYNAMIC SYMBOLS

```
ID     Sym Clr ID     Sym Clr ID     Sym Clr ID     Sym Clr
------ --- --- ------ --- --- ------ --- --- ------ --- ---
1OHR    0  W   2OHR    0  W   3OHR    0  W   4OHR    0  W
5OHR    0  W   7OHR    0  W   8DHR    D  W   8FHR    D  W
8HR     H  7   8HRA    8  G   8HRB    8  G   8HRC    0  W
8HRD    8  G   8HRE    8  G   8HRF    8  G   8HRH    8  G
8HRJ    8  G   8HRK    8  G   8HRL    8  G   8HRV    8  G
8OHR    0  W   9OHR    0  W   A8HR    0  W   AHR     0  W
AOHR    0  W   B8HR    0  W   BHR     0  W   BOHR    0  W
C8HR    0  W   CHR     0  W   DHR     0  W   DOWN8   0  W
DOWN9   D  W   DOWNO   D  W   E8HR    0  W   EHR     0  W
FHR     0  W   GHR     0  W   H8HR    0  W   HHR     0  W
HR9A    H  G   HR9B    9  G   HR9C    9  G   HR9D    9  G
HR9E    9  G   HR9F    9  G   HR9G    9  G   HR9H    9  G
HR9J    9  G   HR9K    9  G   HR9L    9  G   HR9V    9  G
J8HR    0  W   JHR     0  W   JT8     8  B   JT8A    A  B
JT8B    B  B   JT8C    C  B   JT8D    D  B   JT8E    E  B
JT8F    F  B   JT8H    H  B   JT8J    J  B   JT8K    K  B
JT8L    L  B   JT8V    V  B   JT9     9  G   JT9A    A  G
JT9B    B  G   JT9C    C  G   JT9D    D  G   JT9E    E  G
JT9F    F  G   JT9G    G  G   JT9H    H  G   JT9J    J  G
JT9K    K  G   JT9L    L  G   JT9V    V  G   K8HR    0  W
KHR     0  W   L8HR    0  W   LHR     0  W   O1      1  R
O10     X  R   O11     Y  R   O12     Z  R   O2      2  R
O3      3  R   O4      4  R   O5      5  R   O61     6  R
O62     A  R   O7      7  R   O8      8  R   O9      9  R
OHR1    8  G   OHR10   8  G   OHR11   8  G   OHR12   8  G
OHR2    8  G   OHR3    8  G   OHR4    8  G   OHR5    8  G
OHR61   8  G   OHR62   8  G   OHR7    8  G   OHR8    8  G
OHR9    8  8   OLY     O  R   8A      A  7   8B      B  7
8C      C  7   8D      D  7   8E      E  7   8F      F  7
8H      H  7   8J      J  7   8K      K  7   8L      L  7
8V      V  7   JT8     .  7   JT9     .  G   JT9A    A  G
JT9B    B  G   JT9C    C  G   JT9D    D  G   JT9E    E  G
JT9F    F  G   JT9G    G  G   JT9H    H  G   JT9J    J  G
JT9K    K  G   JT9L    L  G   JT9V    V  G   O1      1  5
O10     X  5   O11     Y  5   O12     Z  5   O2      2  5
O3      3  5   O4      4  5   O5      5  5   O61     A  5
O62     B  5   O7      7  5   O8      8  5   O9      9  5
OLY     .  5   RB01    1  2   RB02    2  2   RB03    3  2
RB04    4  2   RB05    5  2   RB06    6  2   RBDU1   0  W
RBDU2   0  W   RBDU3   0  W   RBDU4   0  W   RBDU5   0  W
RBDU6   0  W   RHR1    0  W   RHR2    R  O   RHR3    0  W
RHR4    R  O   RHR5    0  W   RHR6    0  W   TIME    .  6
VHR     0  W   XOHR    0  W   YOHR    0  W   ZOHR    0  W
```

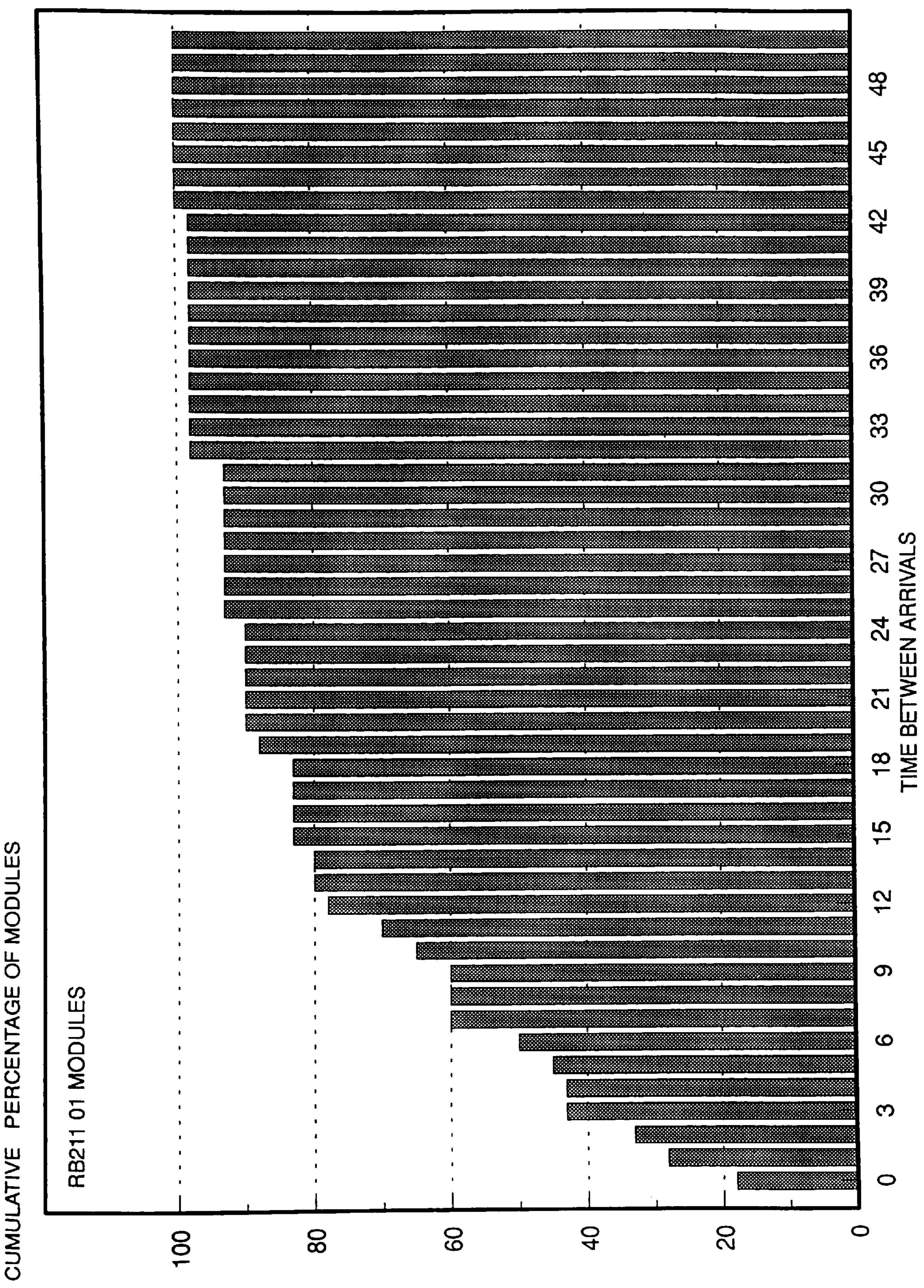
FIGURES AND LABELS

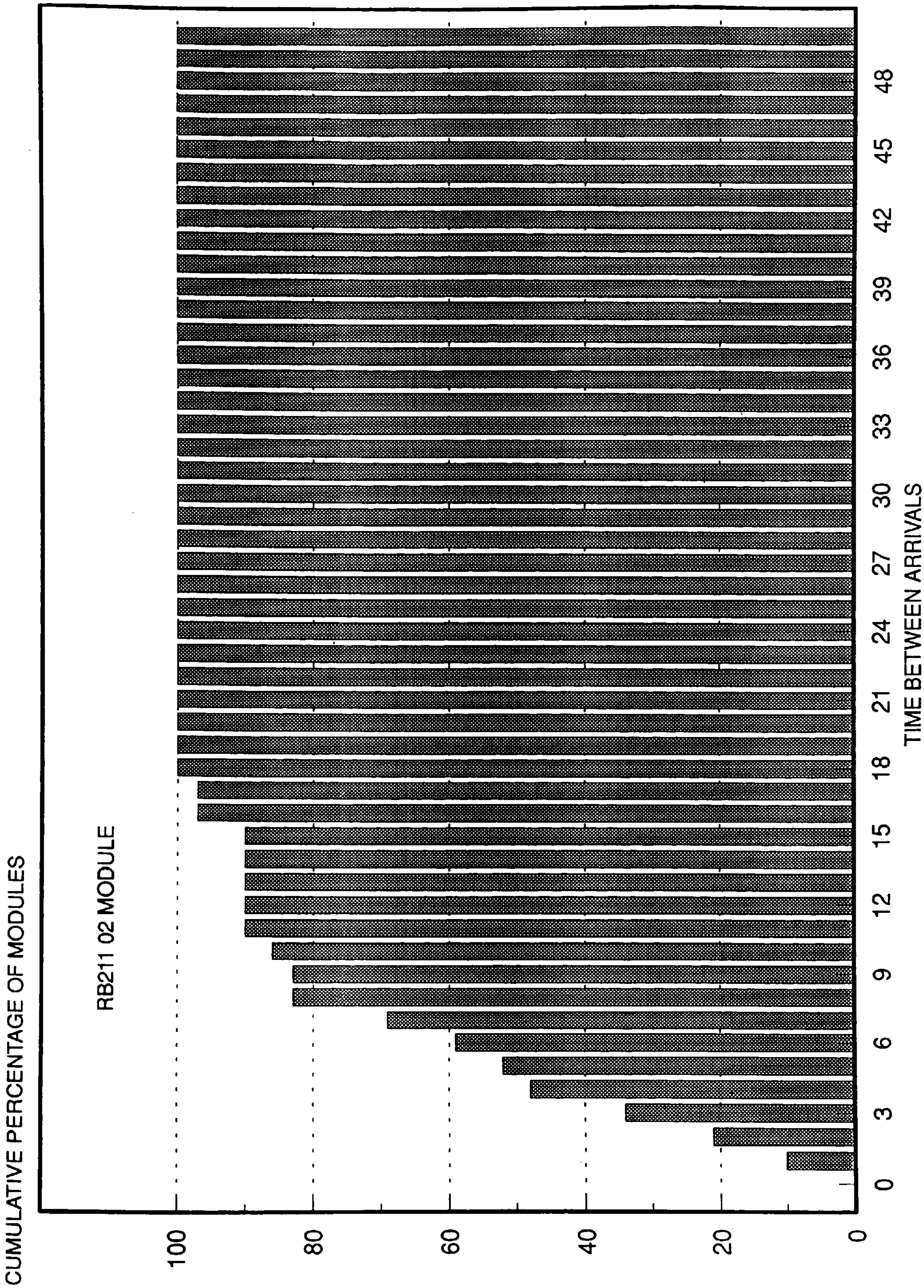
```
Type Clr Row Col Figure
---- --- --- --- ------
VERT Y    4  24 OLY
VERT Y    4  21 JT9
VERT Y    4  27 JT8
VERT Y    4  30 RB211
HORZ Y   24  14 MAN  1  2  3
HORZ Y   16   8 OLY
HORZ Y   13   8 JT8
HORZ Y   10   8 JT9
HORZ Y    7   8 RB211
HORZ Y    8  40 JT8
HORZ Y   14  40 RB211
HORZ Y   11  40 OLY
HORZ Y    5  40 JT9
HORZ Y    8  62 CLEANING BAY
HORZ Y   27  67 CRACK
HORZ Y   29  67 DETECT
HORZ Y   46  57 DETAIL VIEW BAY
HORZ Y    8  48 Q FOR CLEAN
HORZ Y   35  67 Q FOR
HORZ Y   37  67 DETAIL
HORZ Y   39  67 VIEW BAY
```

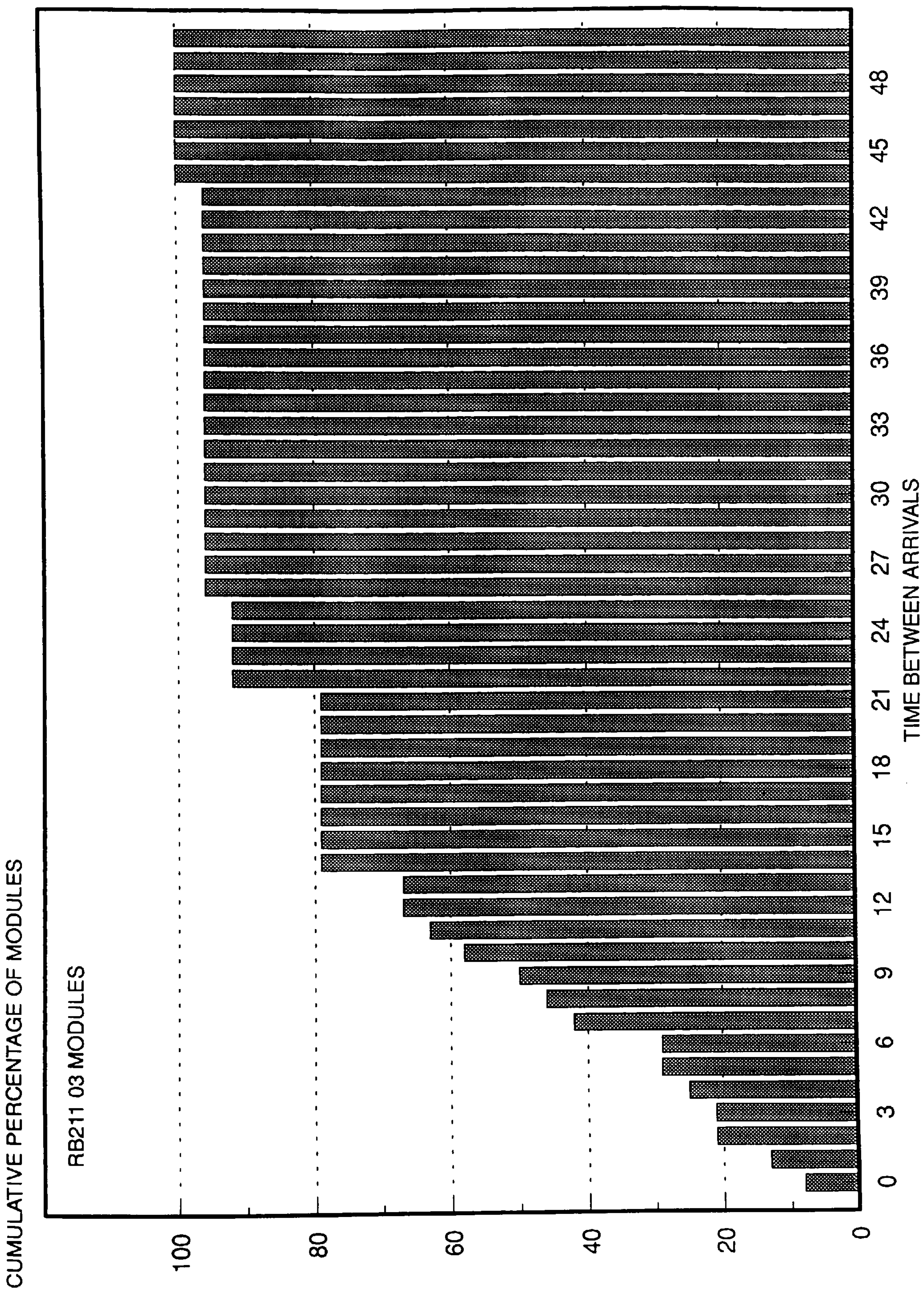
```
HORZ Y   17  67 Q FOR
HORZ Y   19  67 CRACK
HORZ Y   21  67 DETECT
SIGN YB  33  23 R12 D7 L12 U7 R1
HORZ Y   35  24 TIME
HORZ Y   39  24 DAY
SIGN YB  28  11 U1 R20 D2 L20 U1
HORZ 8   28  12 INPUT BUSINESS UNIT
LINE 8   25  30 L29 U22 R75 D44 L22 U22 L25

END
```

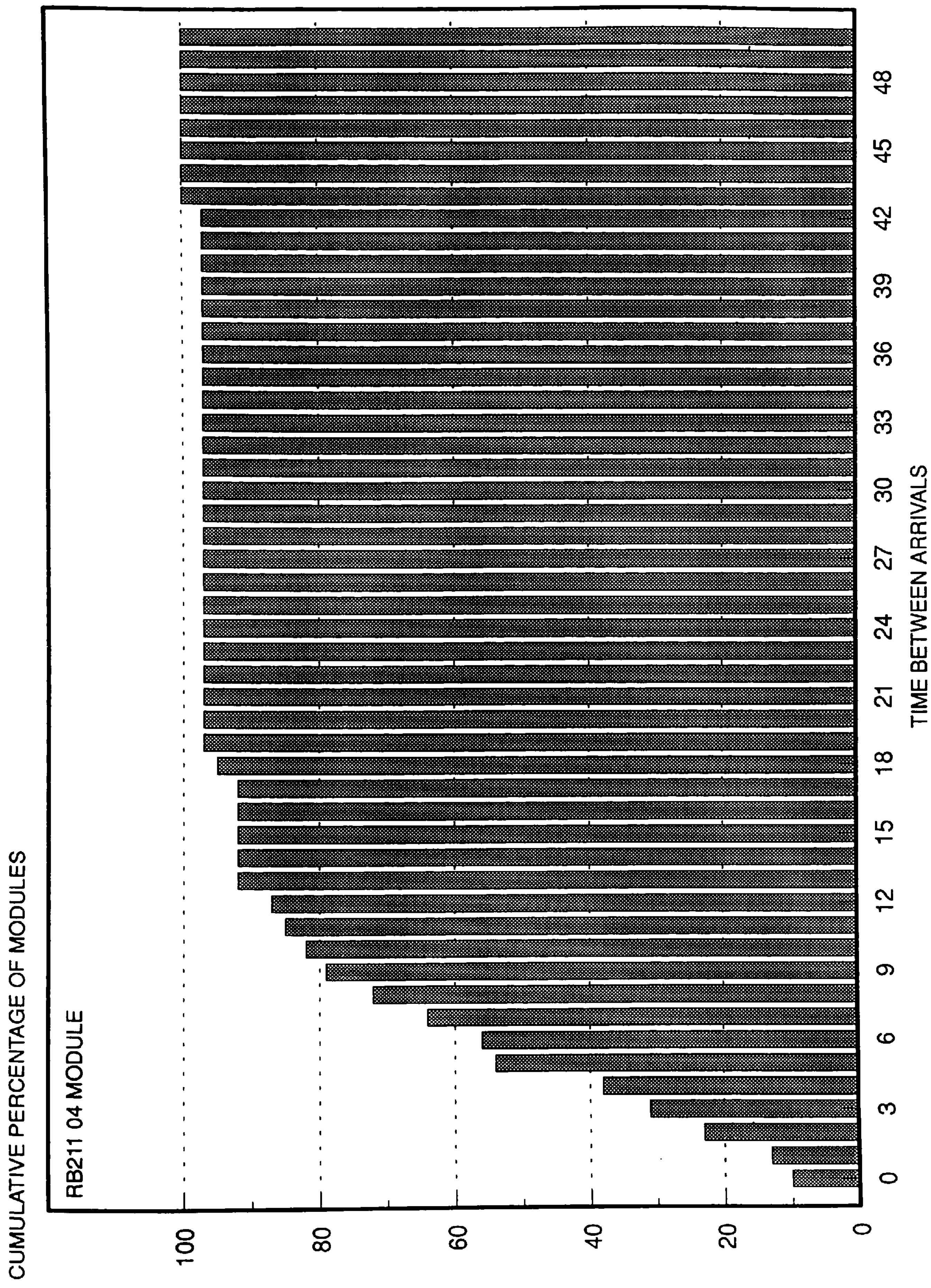
Appendix 5

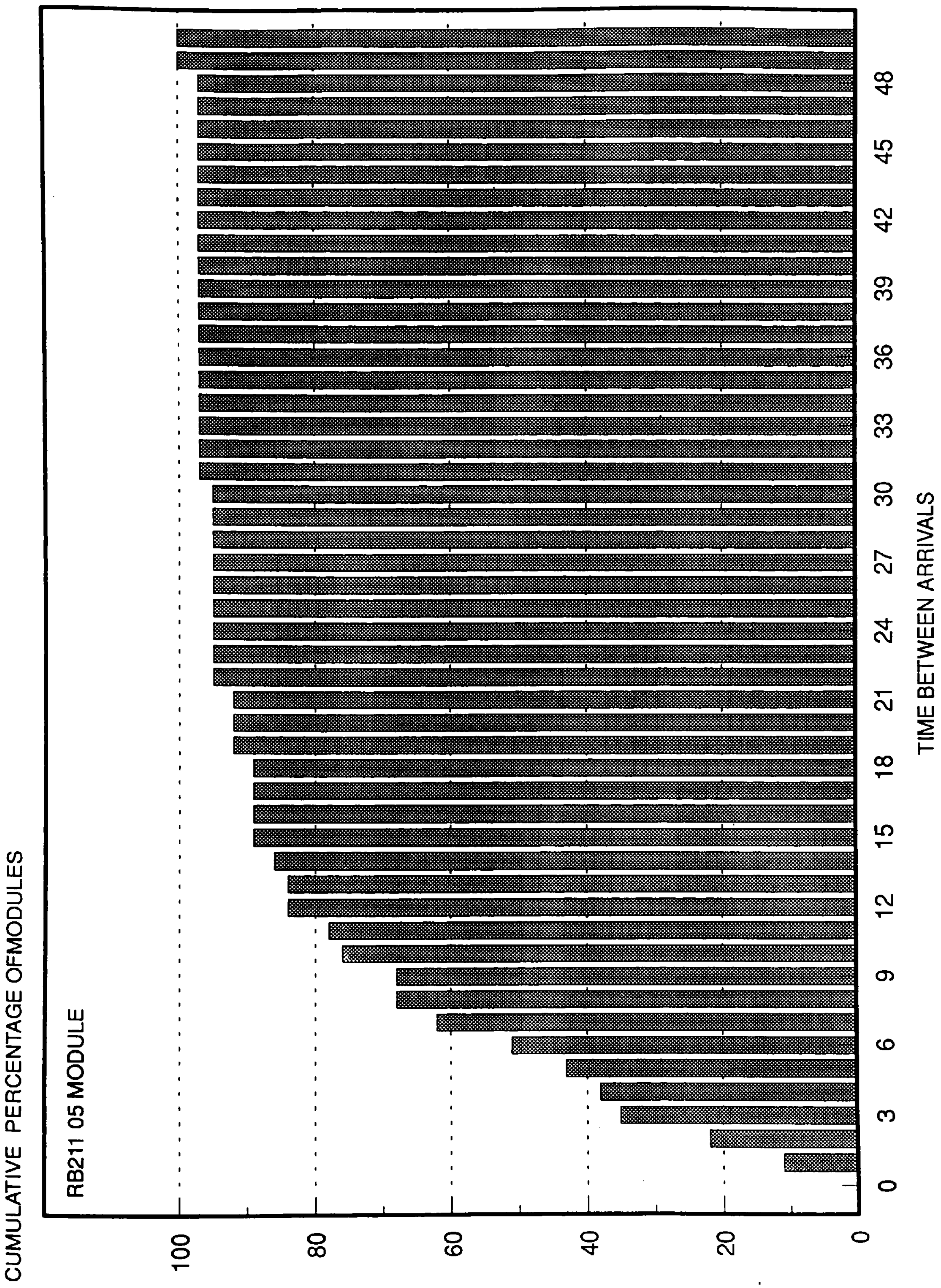
Input frequency distributions


CUMULATIVE PERCENTAGE OF MODULES
RB211 01 MODULES
0
20
40
60
80
100
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
TIME BETWEEN ARRIVALS

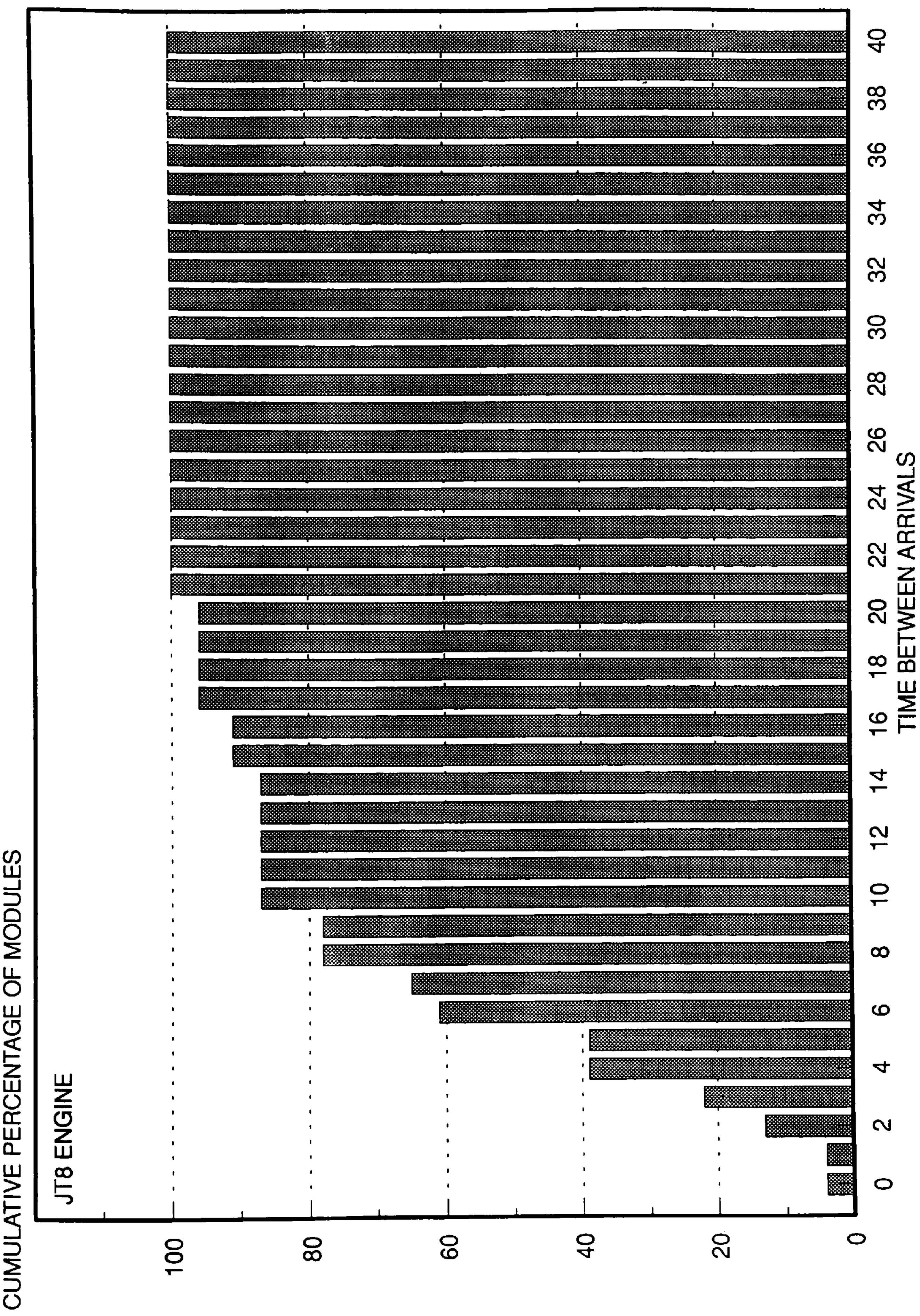

CUMULATIVE PERCENTAGE OF MODULES
RB211 02 MODULE
TIME BETWEEN ARRIVALS
0
20
40
60
80
100
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48

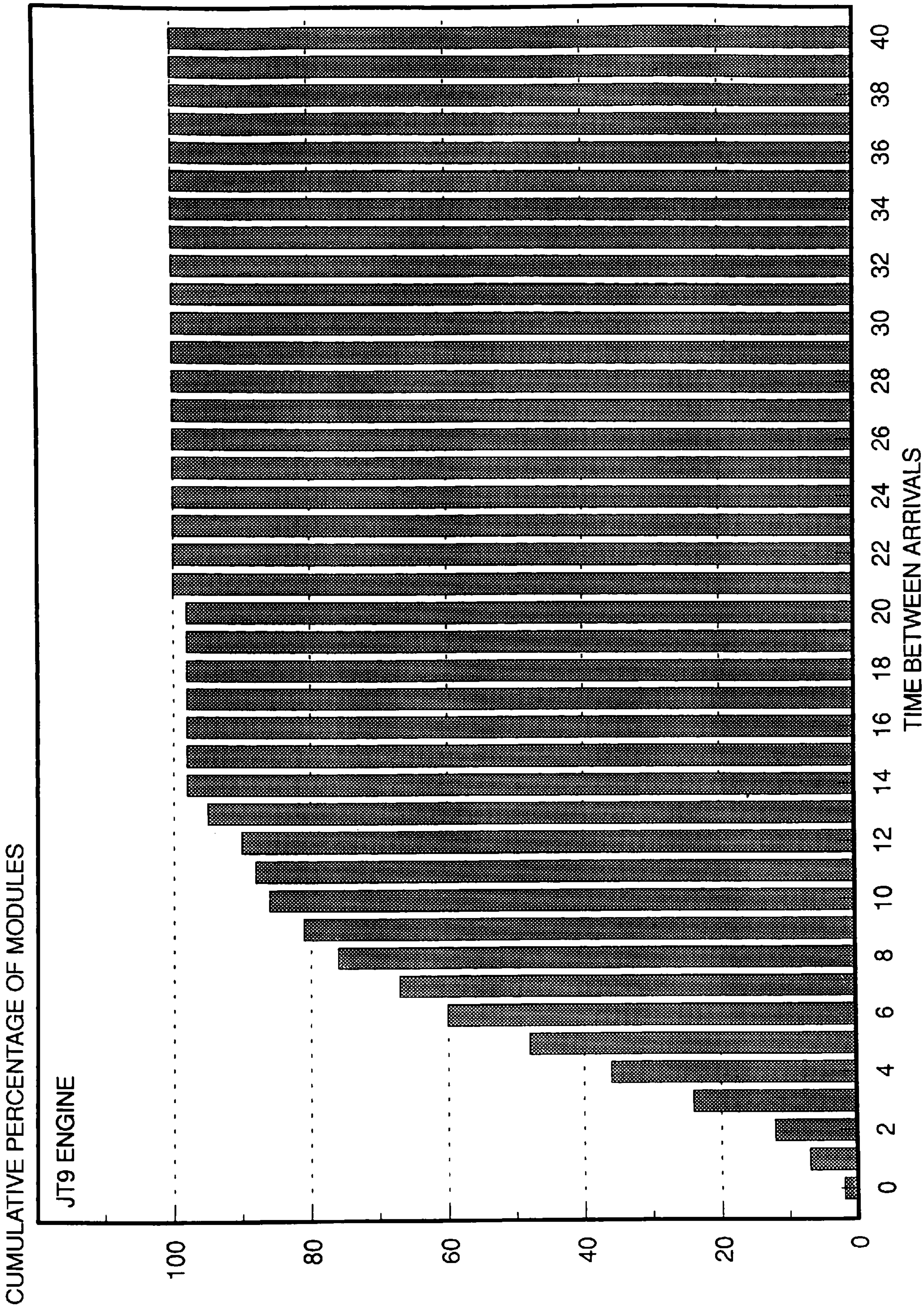

CUMULATIVE PERCENTAGE OF MODULES
RB211 03 MODULES
TIME BETWEEN ARRIVALS
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
0
20
40
60
80
100

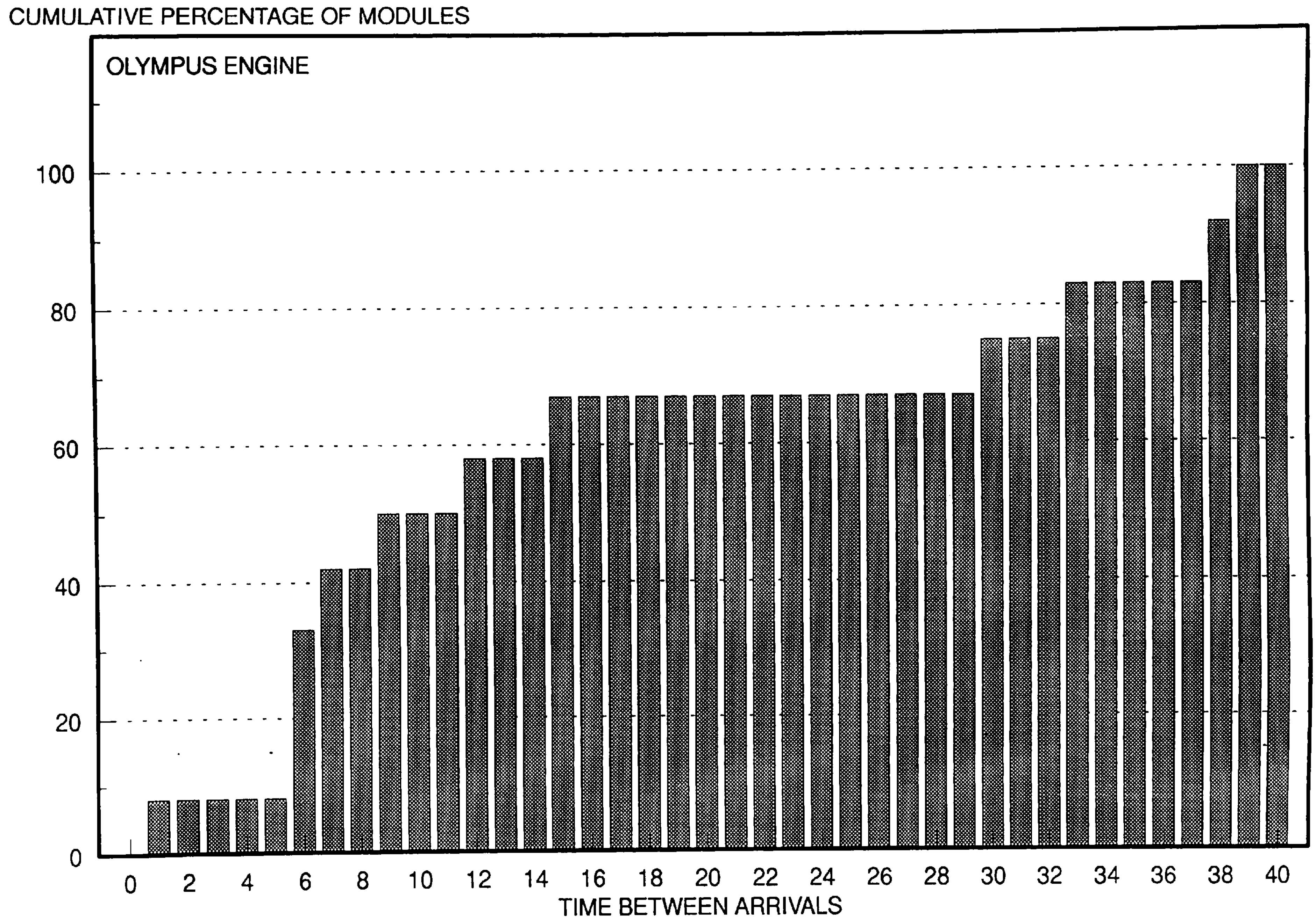

CUMULATIVE PERCENTAGE OF MODULES
RB211 04 MODULE
TIME BETWEEN ARRIVALS
0
20
40
60
80
100
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48



CUMULATIVE PERCENTAGE OFMODULES
RB211 05 MODULE
100
80
60
40
20
0
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
TIME BETWEEN ARRIVALS


CUMULATIVE PERCENTAGE OF MODULES
JT8 ENGINE
0
20
40
60
80
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
TIME BETWEEN ARRIVALS

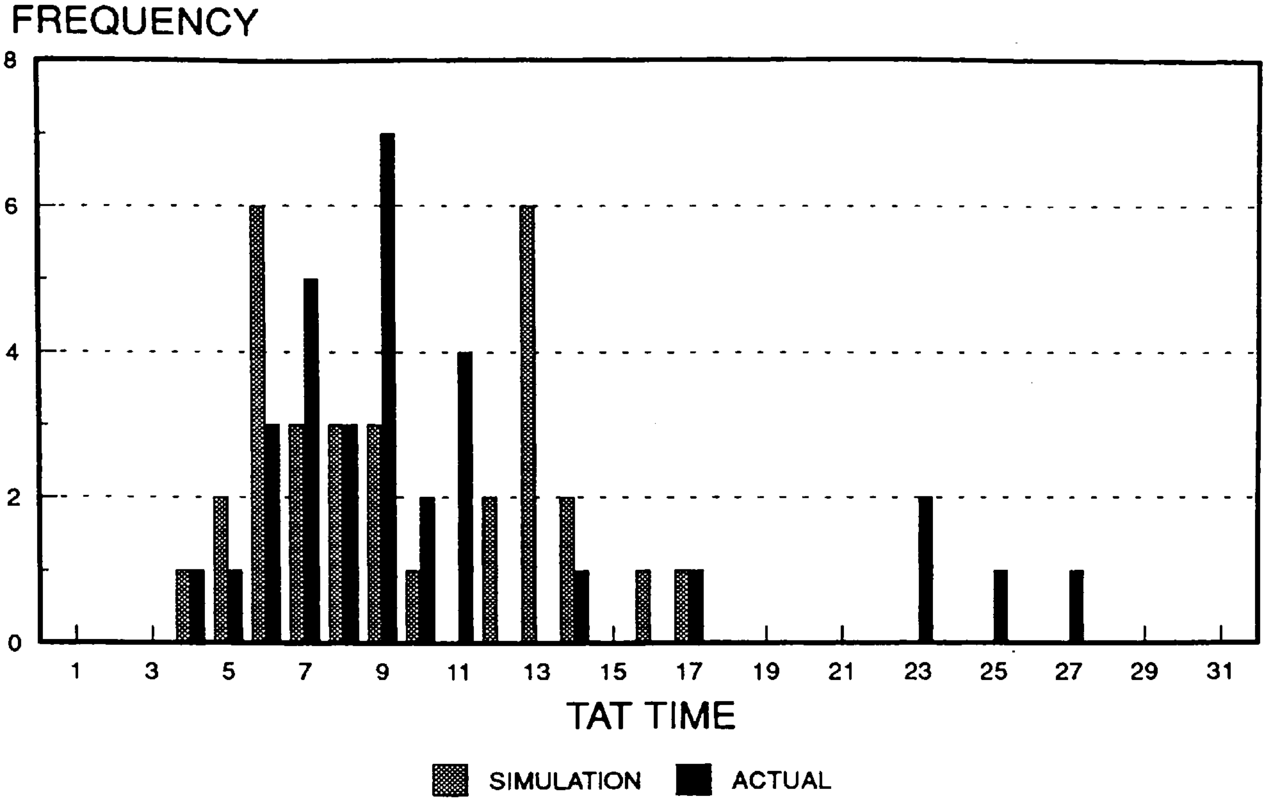

CUMULATIVE PERCENTAGE OF MODULES
JT9 ENGINE
0
20
40
60
80
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
TIME BETWEEN ARRIVALS


CUMULATIVE PERCENTAGE OF MODULES
OLYMPUS ENGINE
100
80
60
40
20
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TIME BETWEEN ARRIVALS

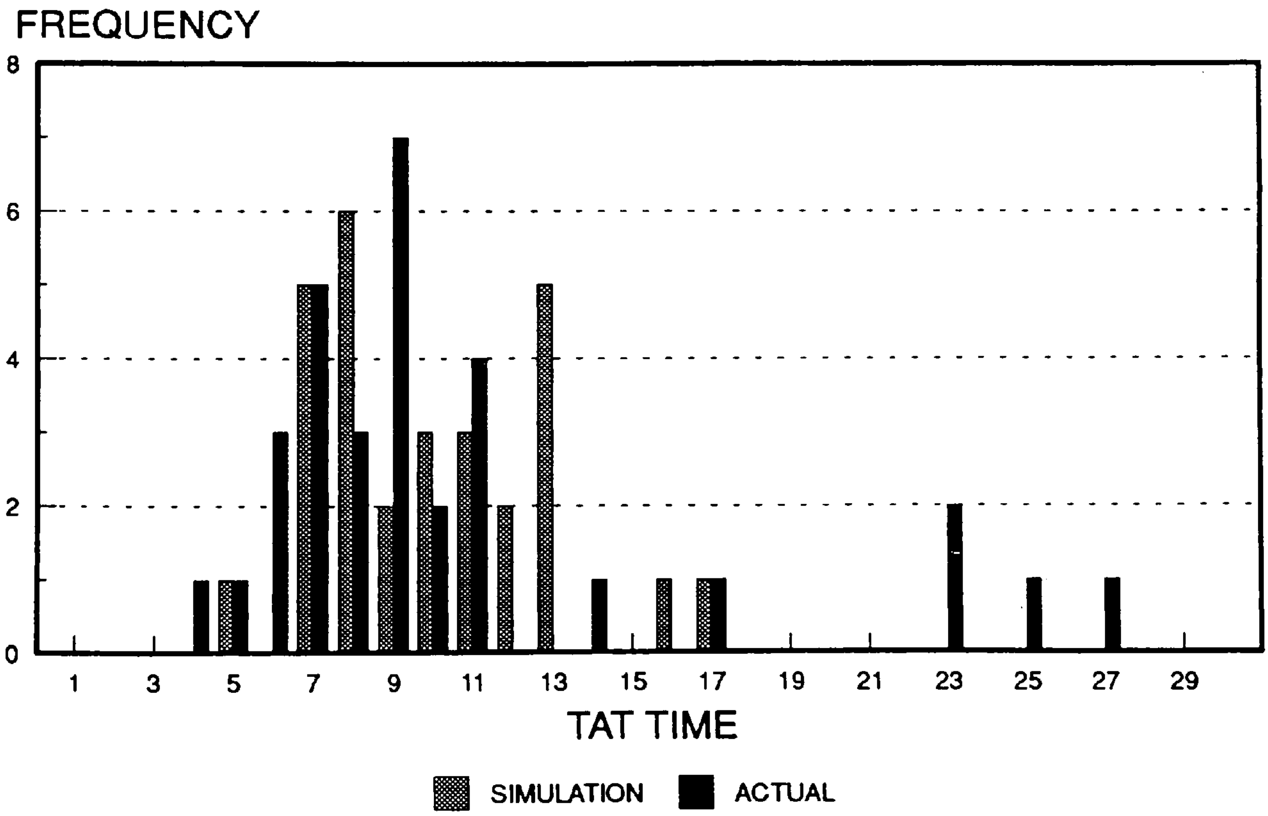
Appendix 6

Graphs showing the simulation figures for the first and last six months of the simulation run vrs the actual figures

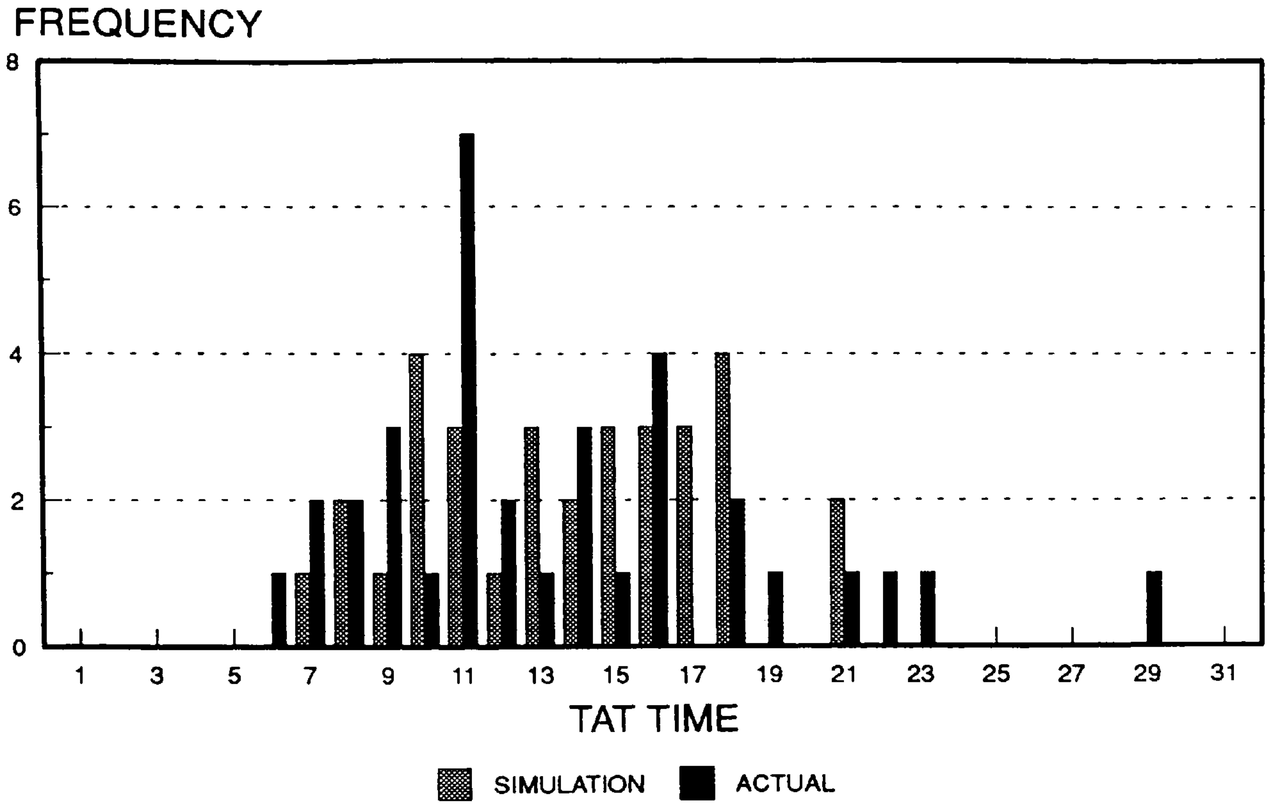
01 SIMULATION VRS ACTUAL (FIRST 6 MTH)



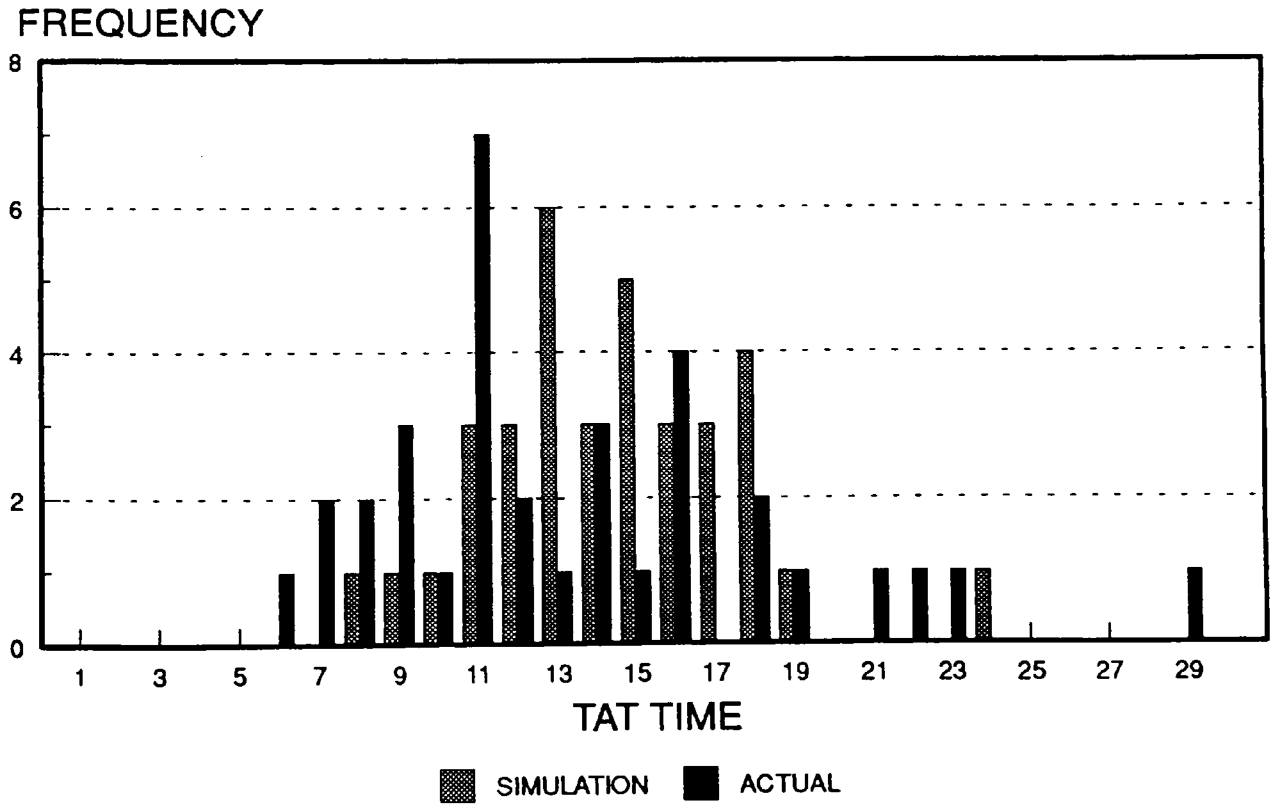
01 SIMULATION VRS ACTUAL (LAST 6MTH)



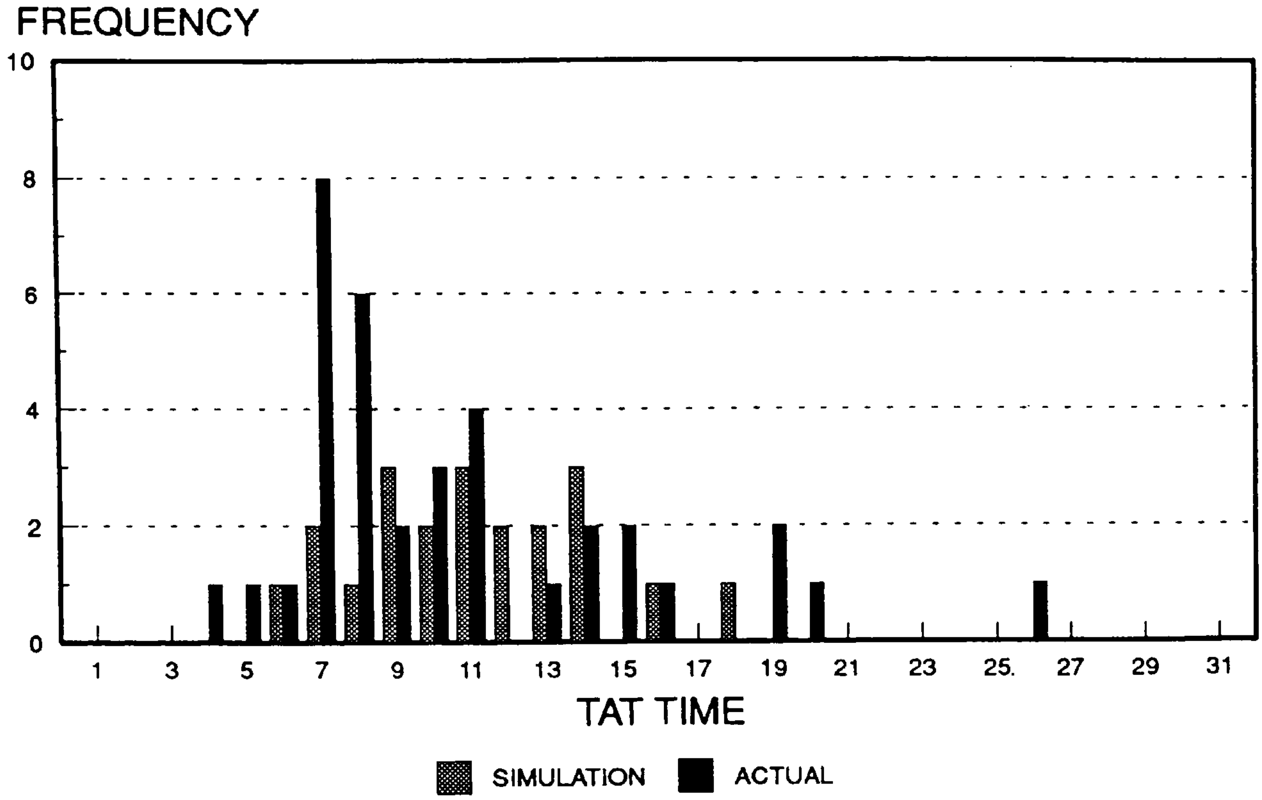
02 SIMULATION VRS ACTUAL (FIRST 6 MTH)



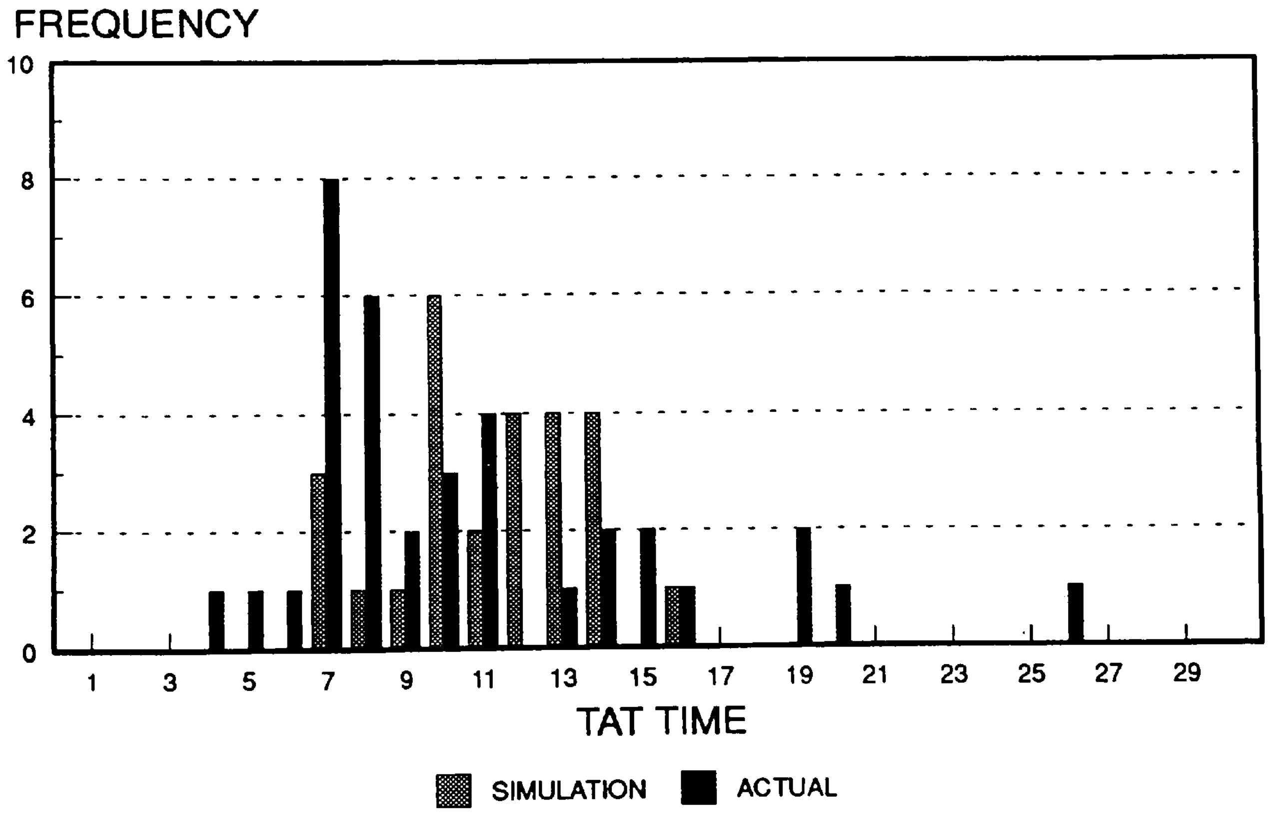
02 SIMULATION VRS ACTUAL (LAST 6MTH)

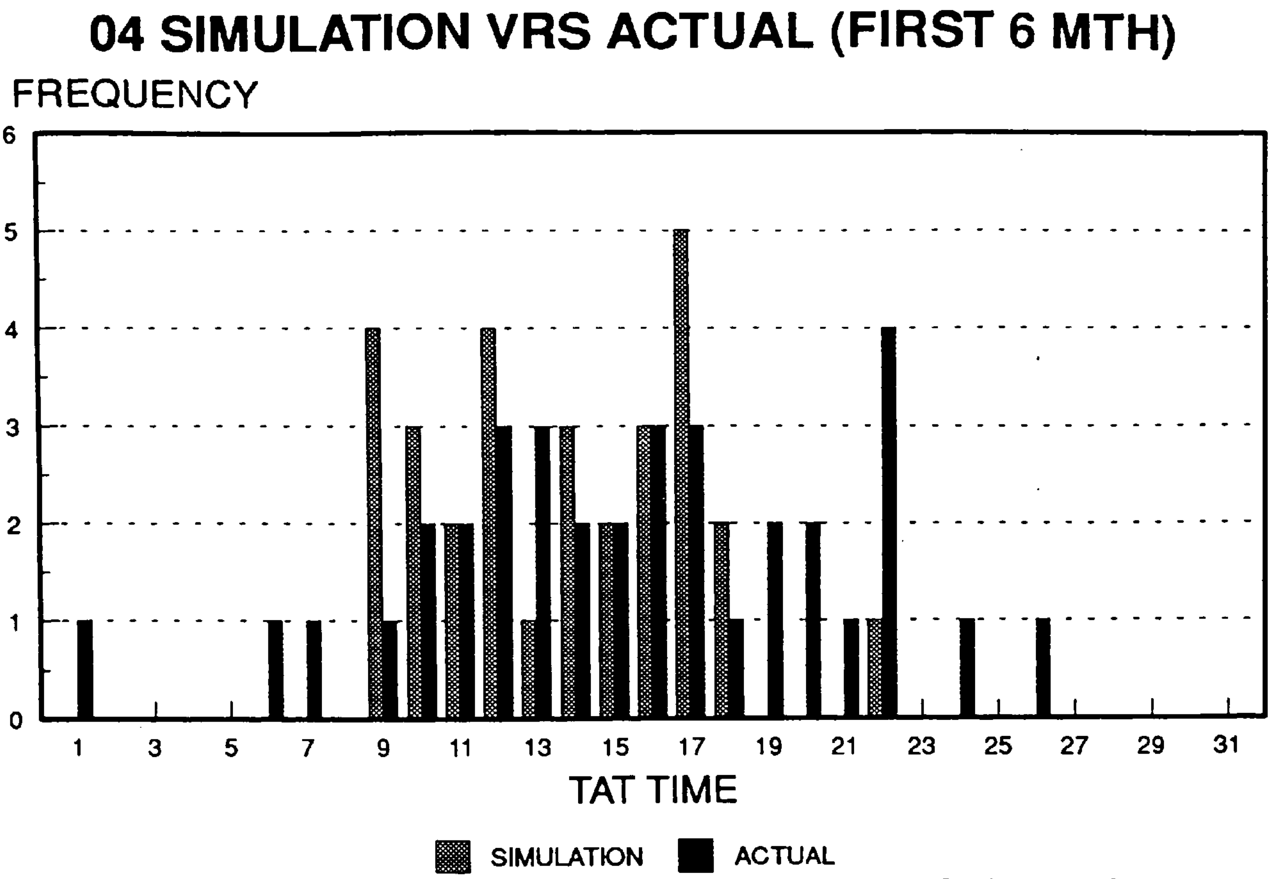


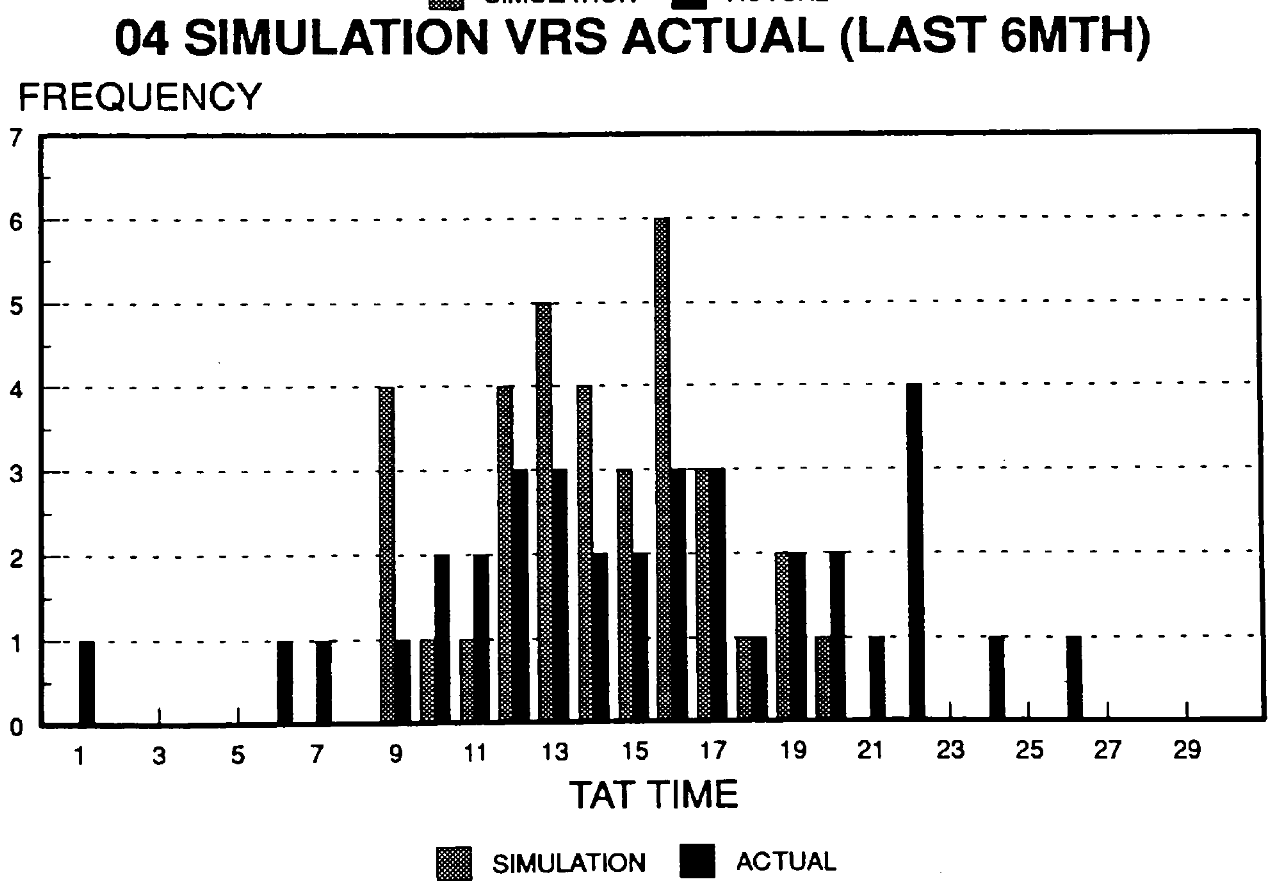
03 SIMULATION VRS ACTUAL (FIRST 6 MTH)

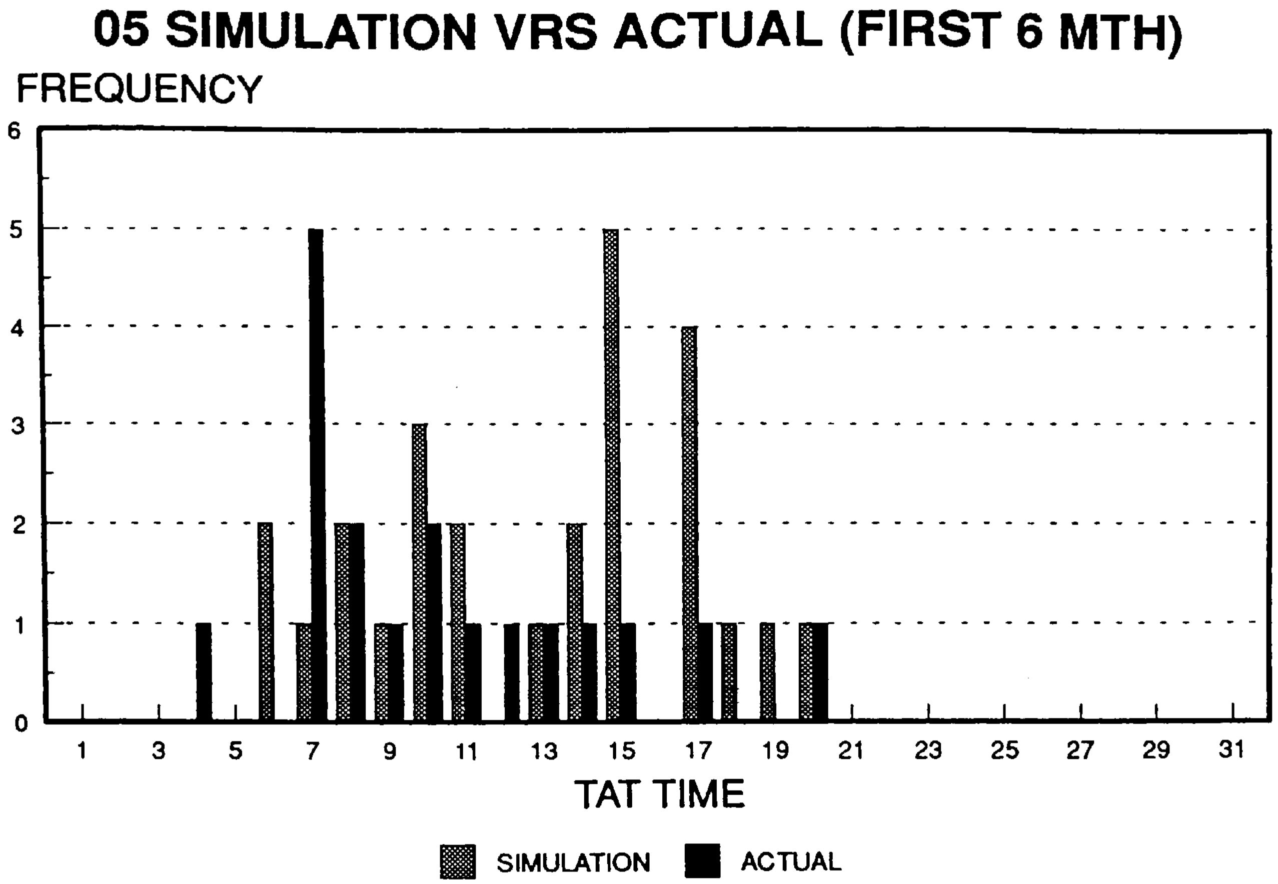


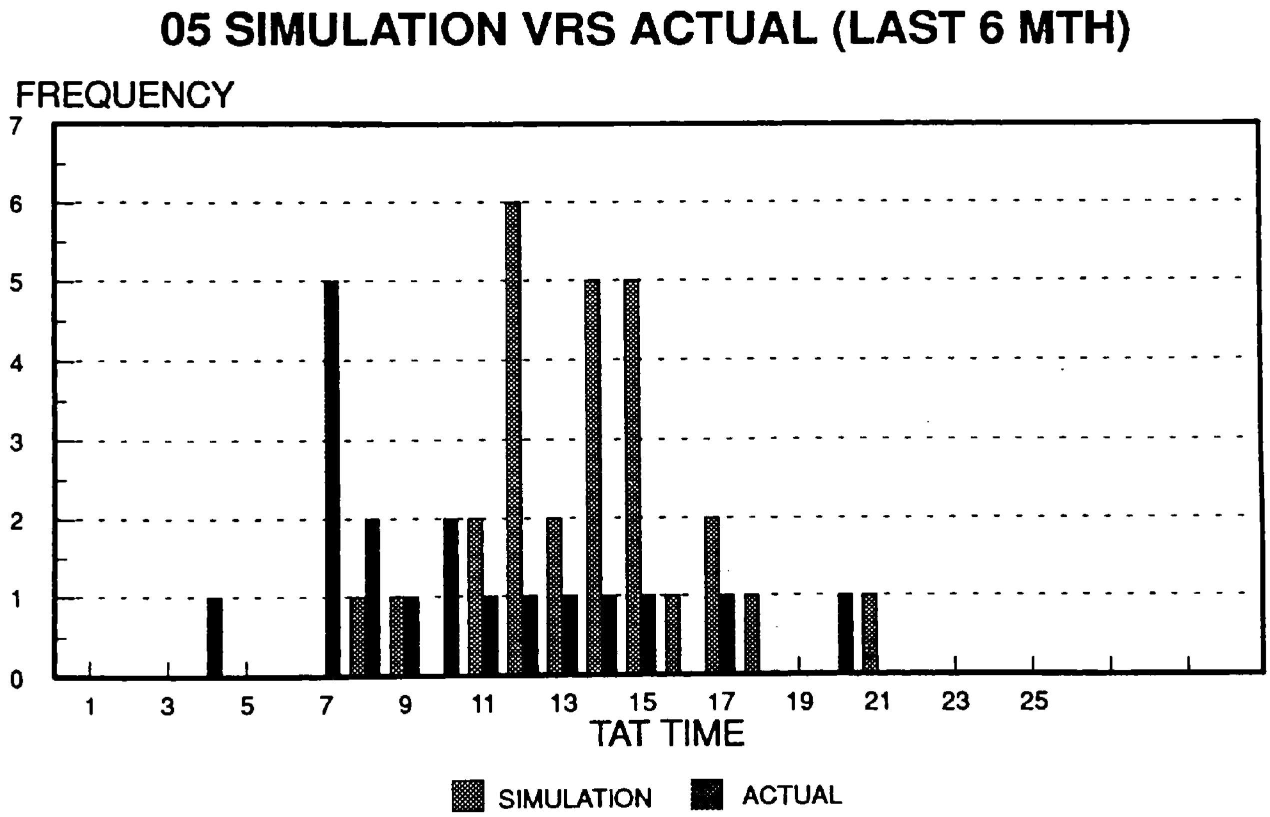
03 SIMULATION VRS ACTUAL (LAST 6MTH)



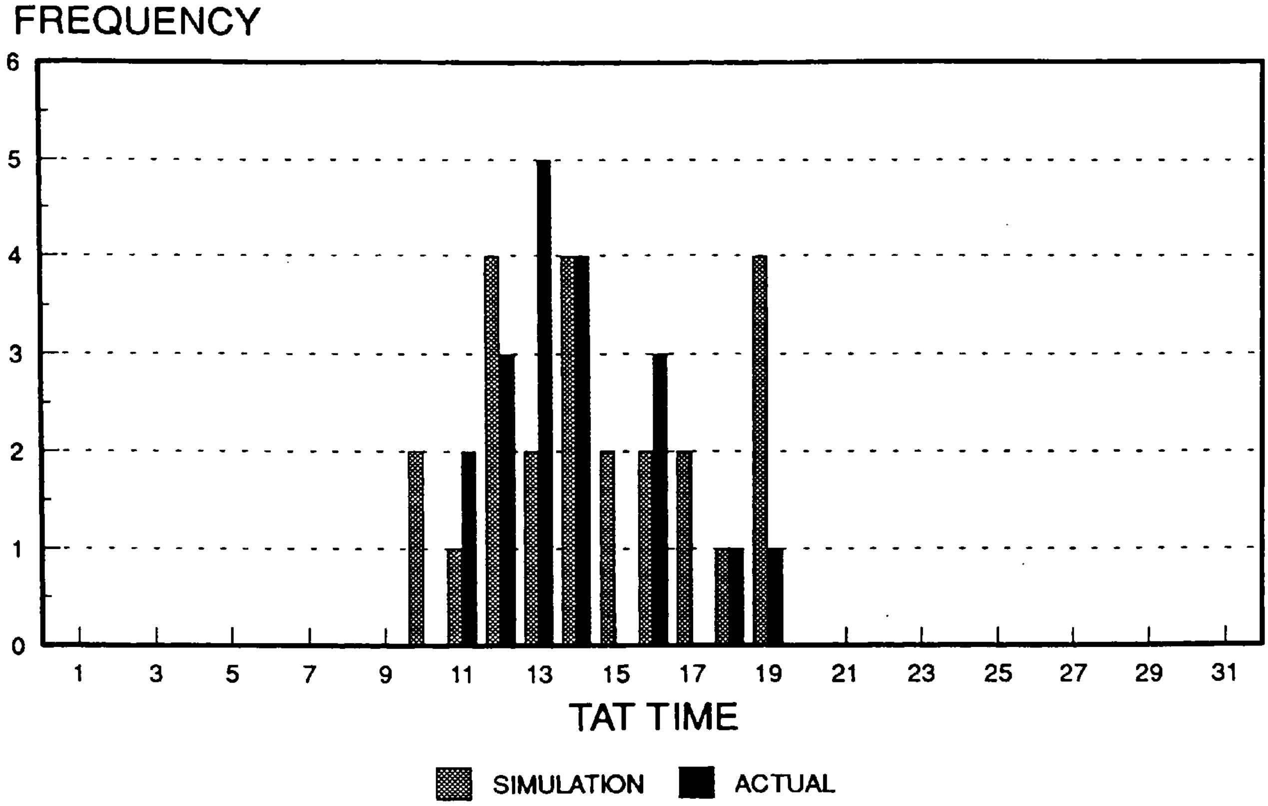

04 SIMULATION VRS ACTUAL (FIRST 6 MTH)
FREQUENCY
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
TAT TIME
SIMULATION
ACTUAL


04 SIMULATION VRS ACTUAL (LAST 6MTH)
FREQUENCY
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
TAT TIME
SIMULATION
ACTUAL

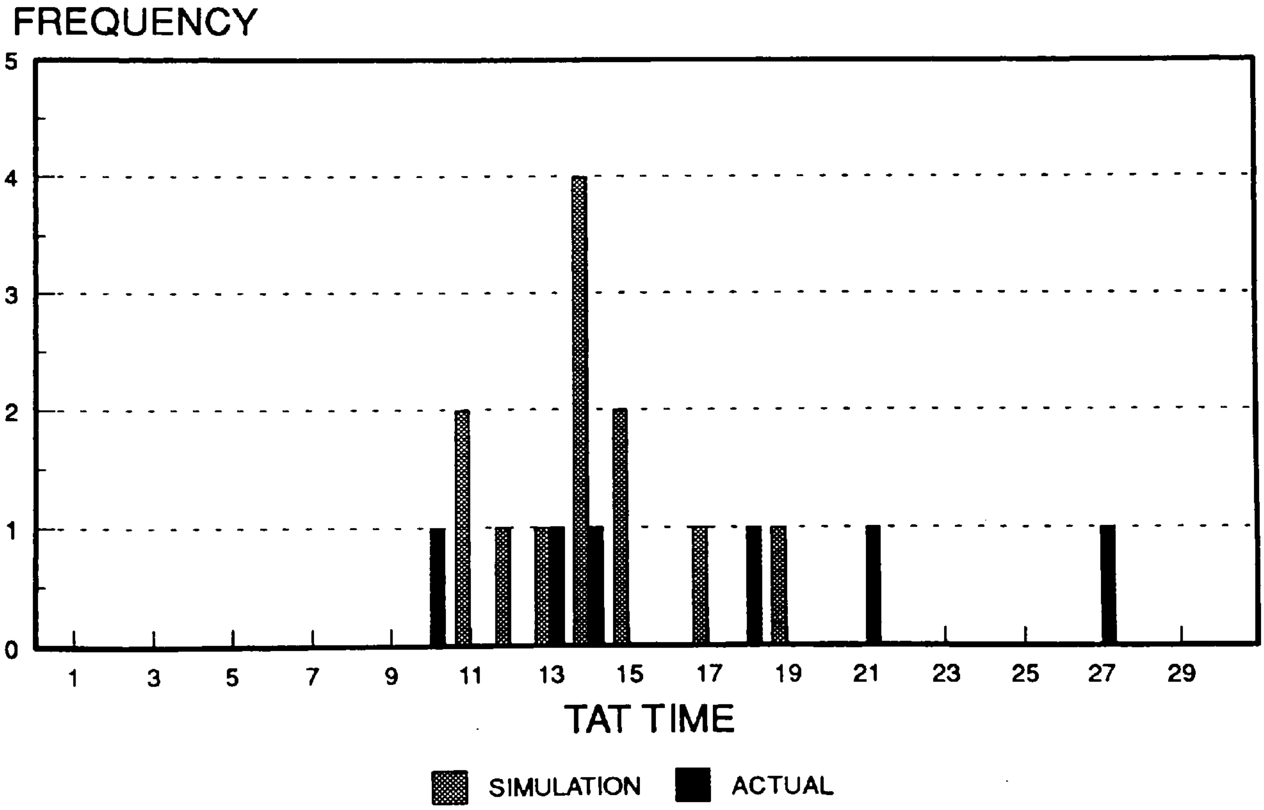

05 SIMULATION VRS ACTUAL (FIRST 6 MTH)
FREQUENCY
0
1
2
3
4
5
6
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
TAT TIME
SIMULATION
ACTUAL


05 SIMULATION VRS ACTUAL (LAST 6 MTH)
FREQUENCY
0
1
2
3
4
5
6
7
1
3
5
7
9
11
13
15
17
19
21
23
25
TAT TIME
SIMULATION
ACTUAL

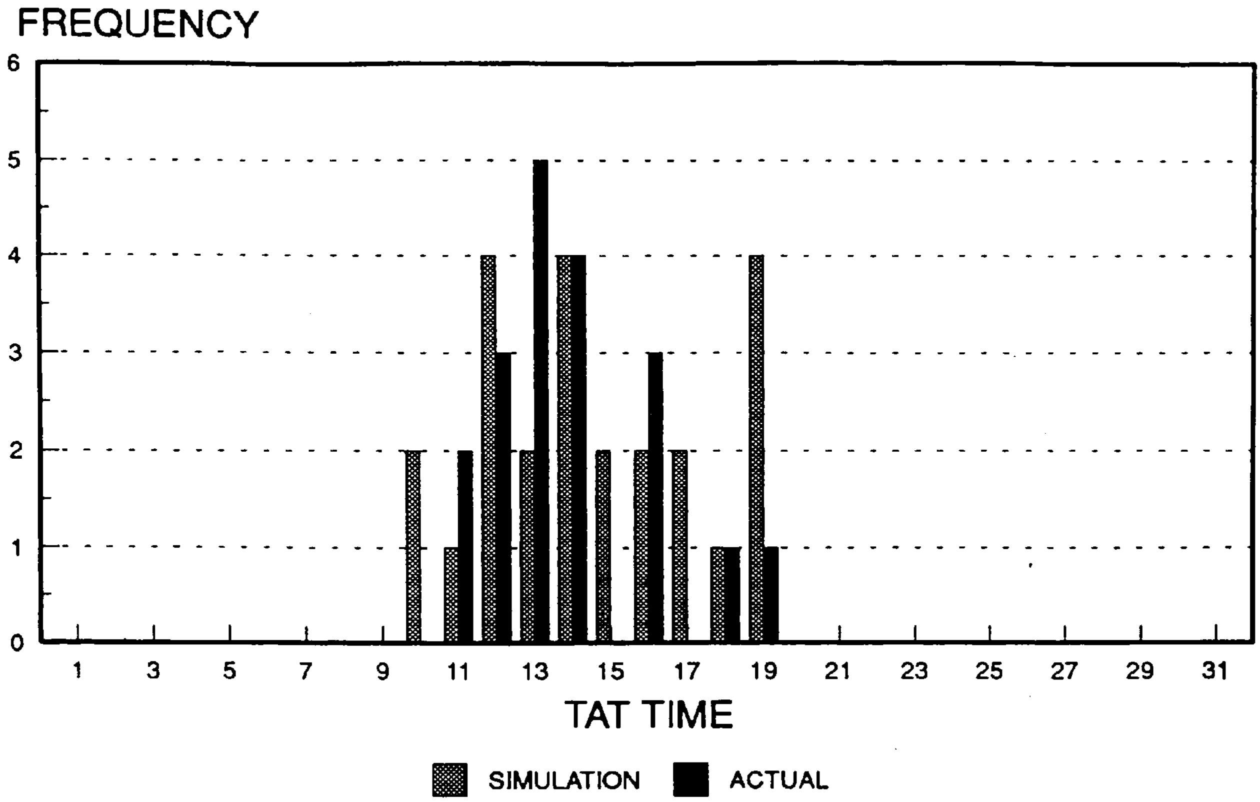
JT8 SIMULATION VRS ACTUAL (FIRST 6 MTH)



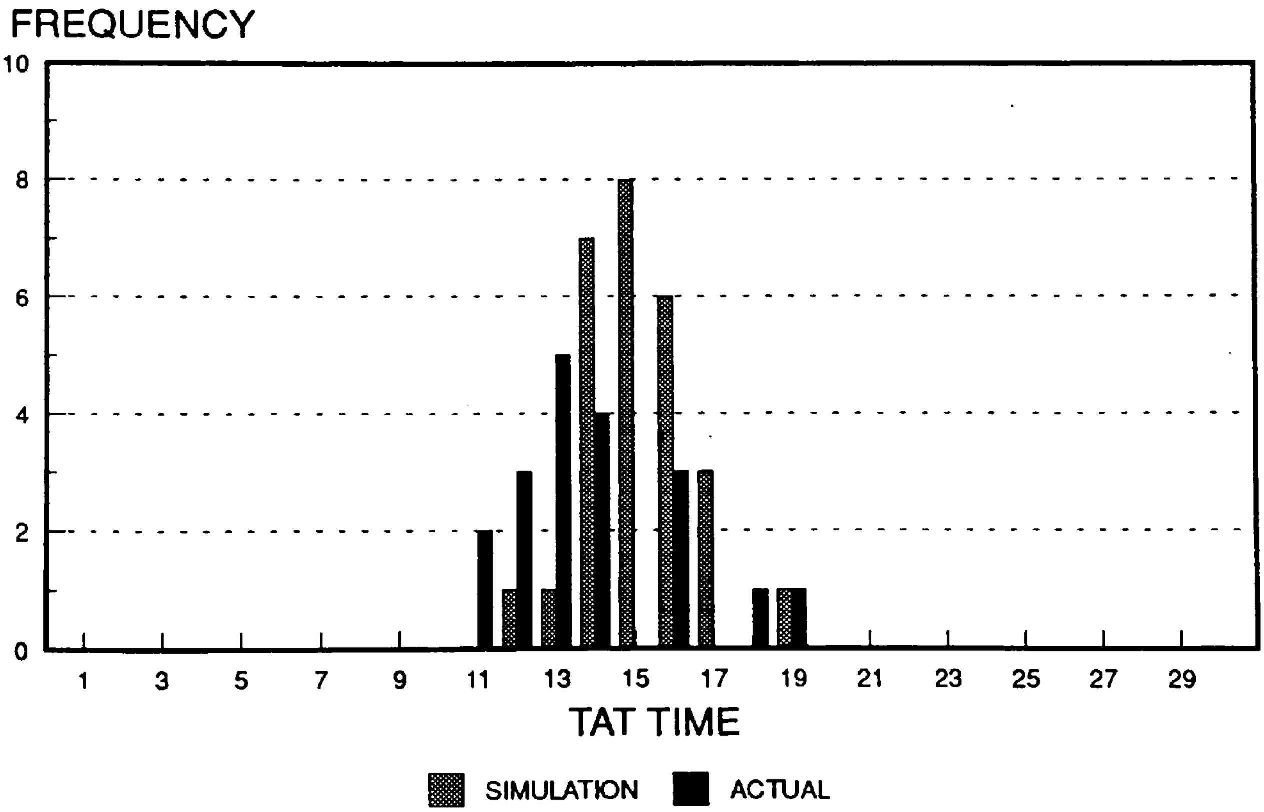
JT8 SIMULATION VRS ACTUAL (LAST 6MTH)

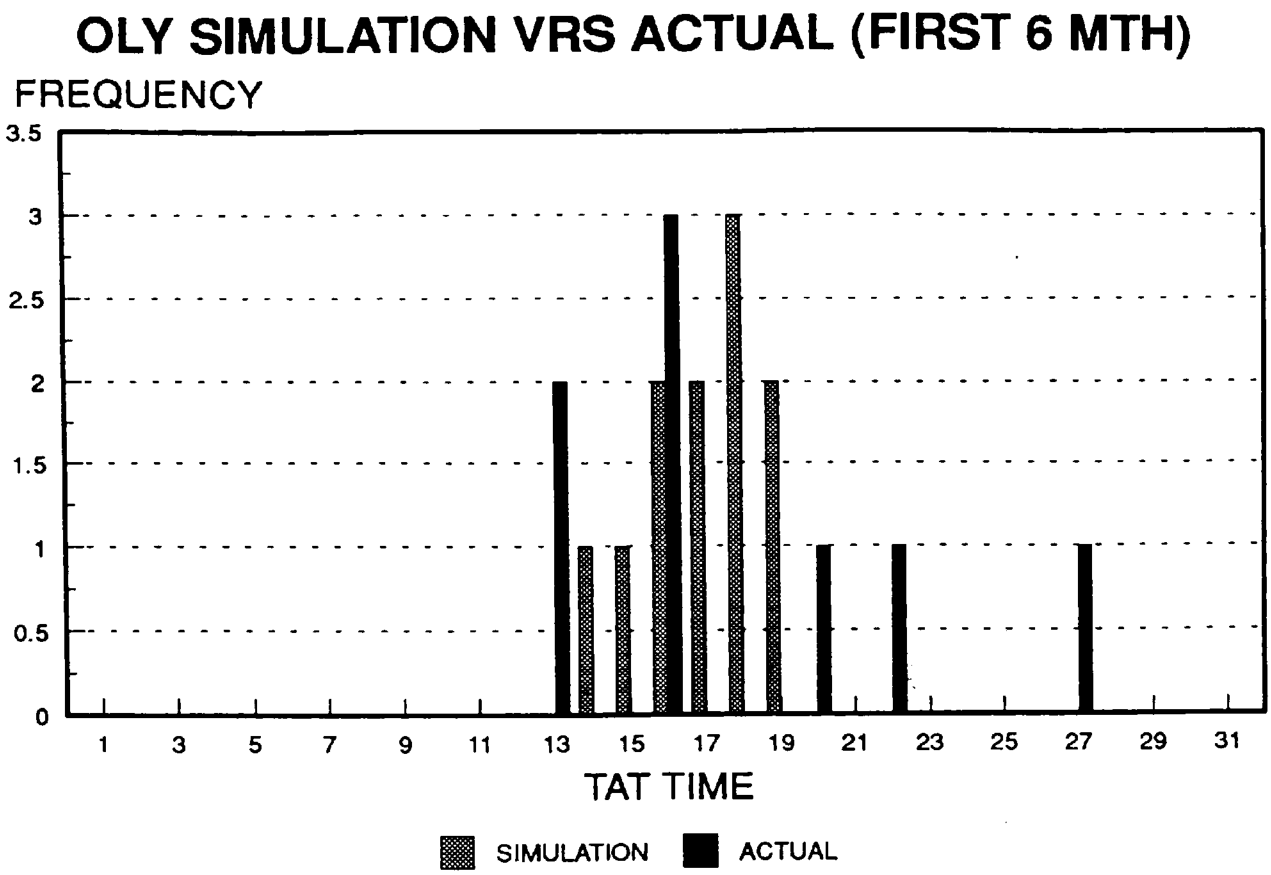


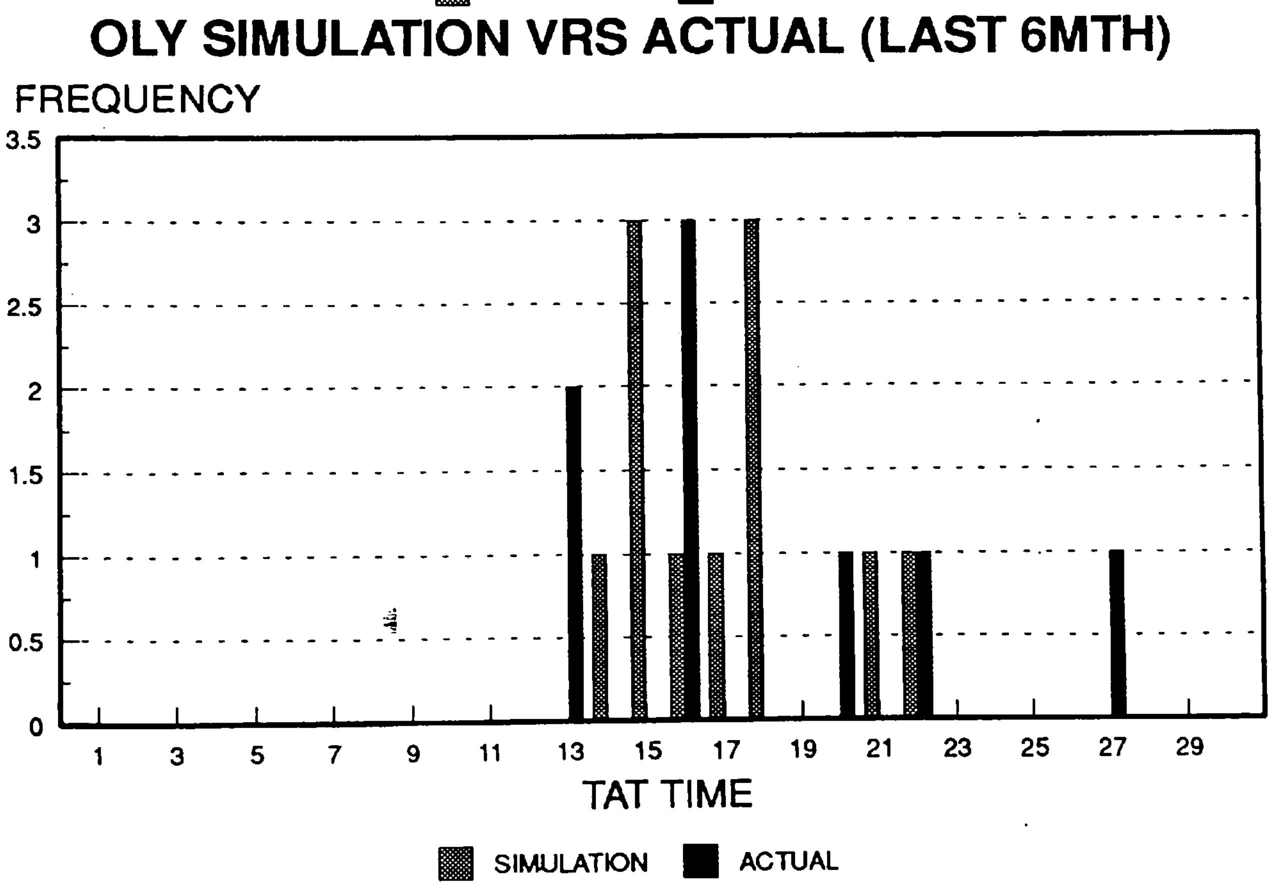
JT9 SIMULATION VRS ACTUAL (FIRST 6 MTH)



JT9 SIMULATION VRS ACTUAL (LAST 6MTH)




OLY SIMULATION VRS ACTUAL (FIRST 6 MTH)
FREQUENCY
3.5
3
2.5
2
1.5
1
0.5
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
TAT TIME
SIMULATION
ACTUAL

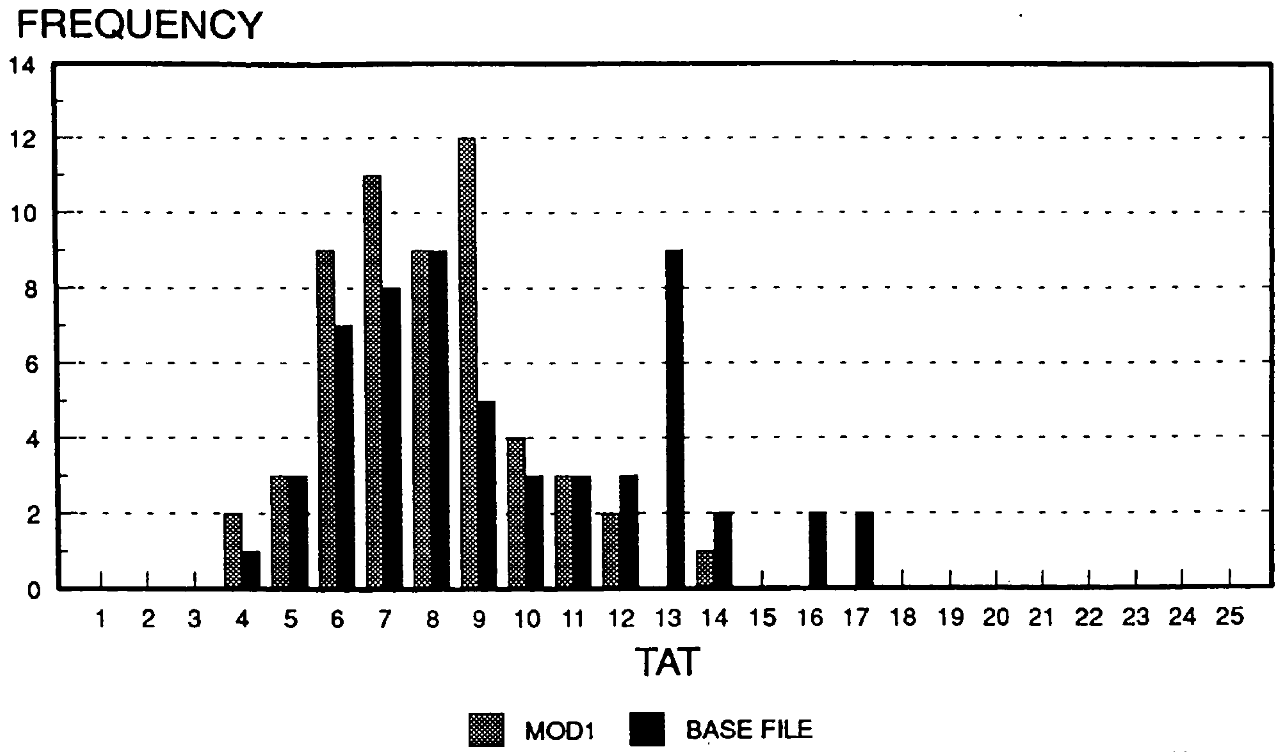

OLY SIMULATION VRS ACTUAL (LAST 6MTH)
FREQUENCY
3.5
3
2.5
2
1.5
1
0.5
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
TAT TIME
SIMULATION
ACTUAL

Appendix 7

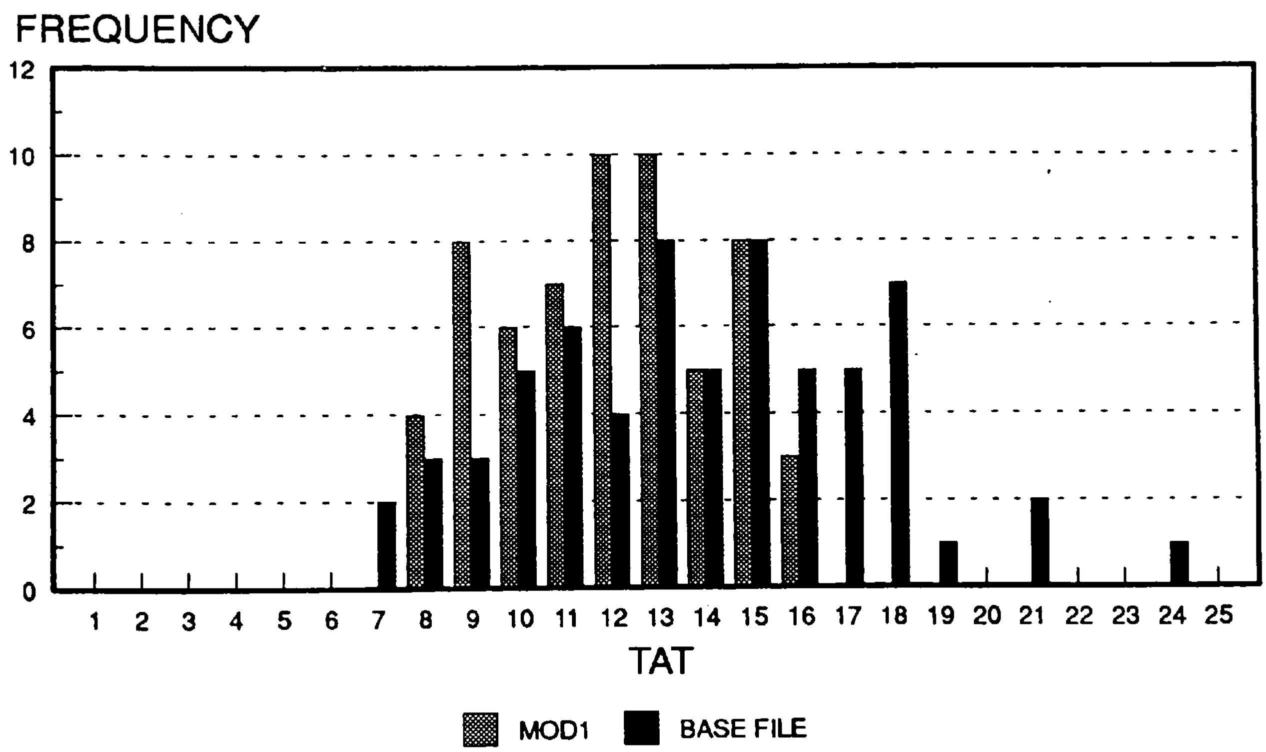
7) Simulation 'what-if' results:

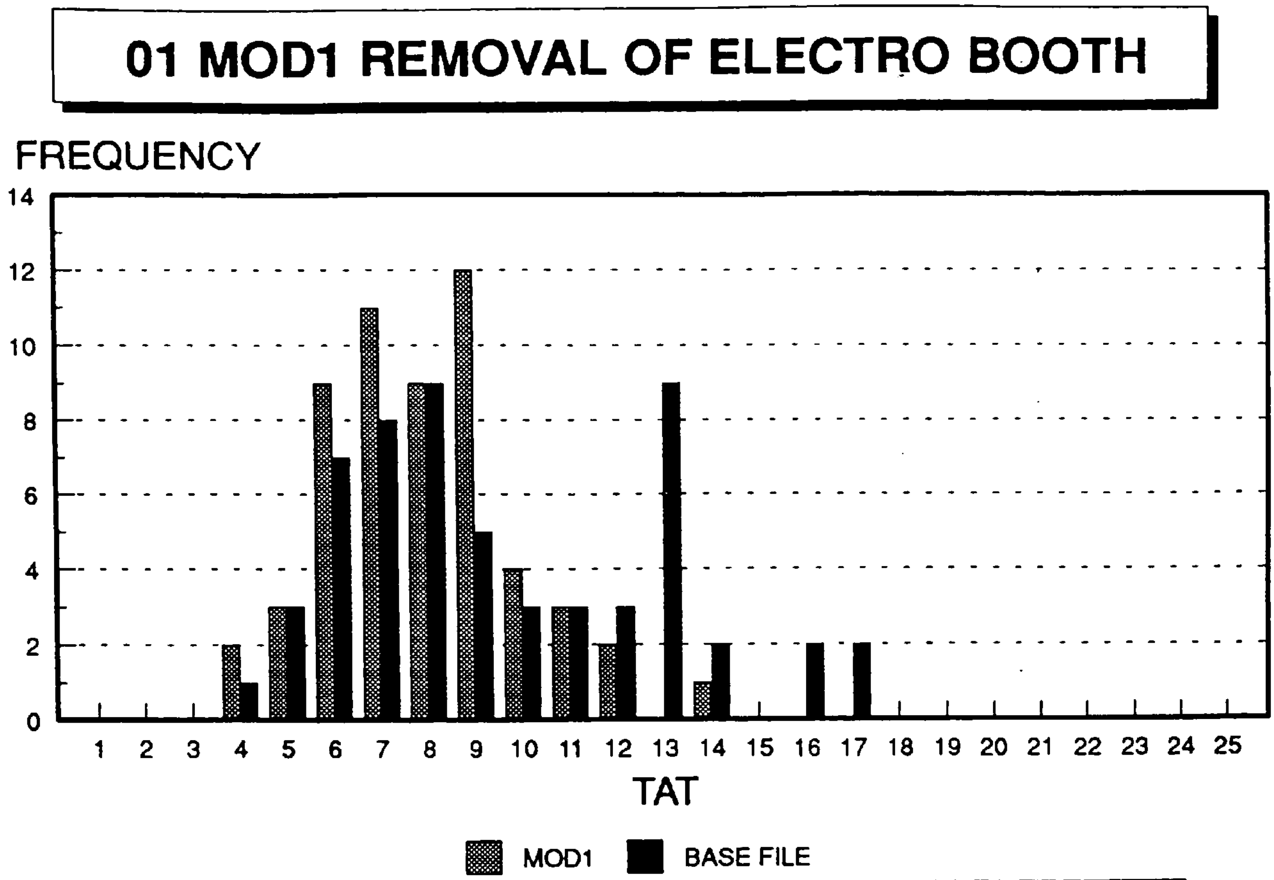
7.1) Change in TAT for the electro-static booth removal

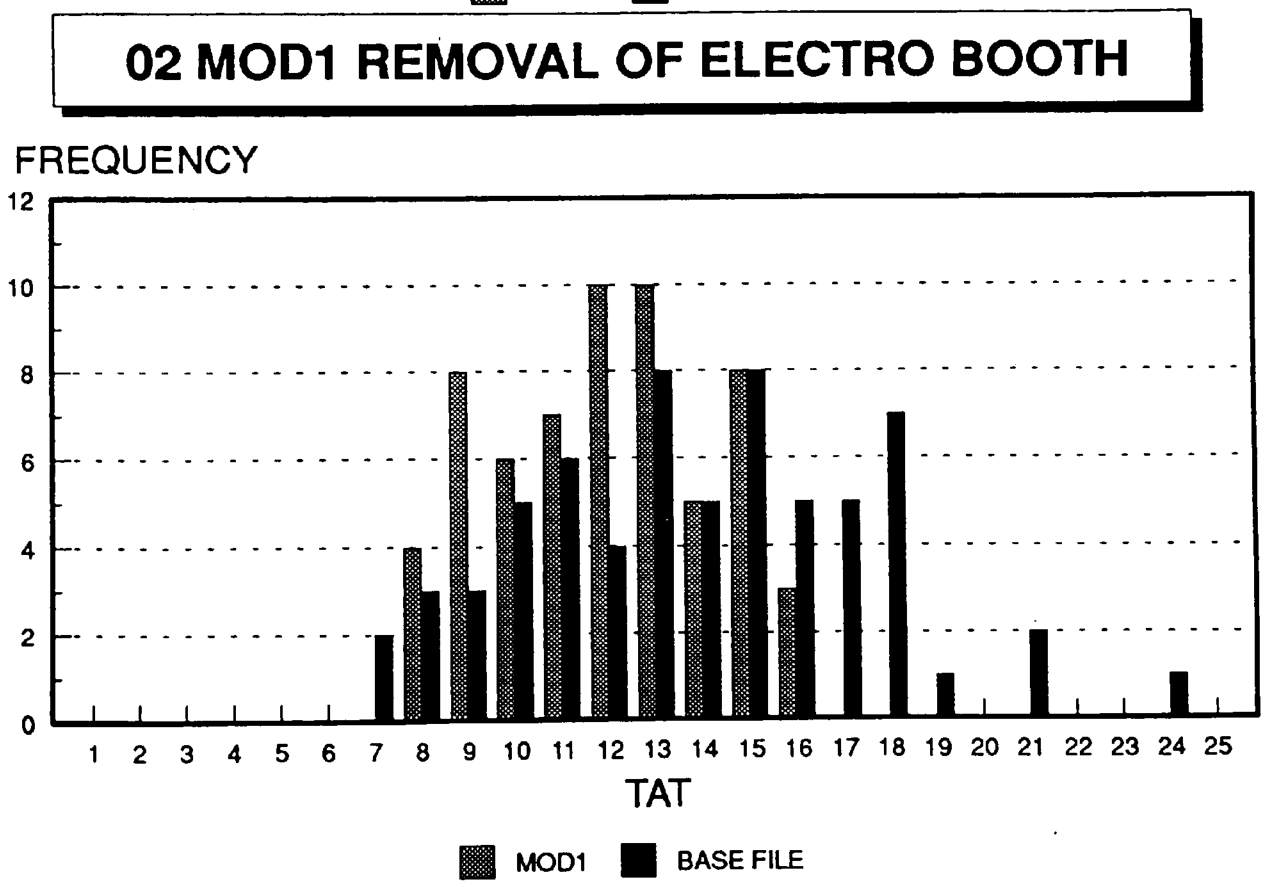
01 MOD1 REMOVAL OF ELECTRO BOOTH



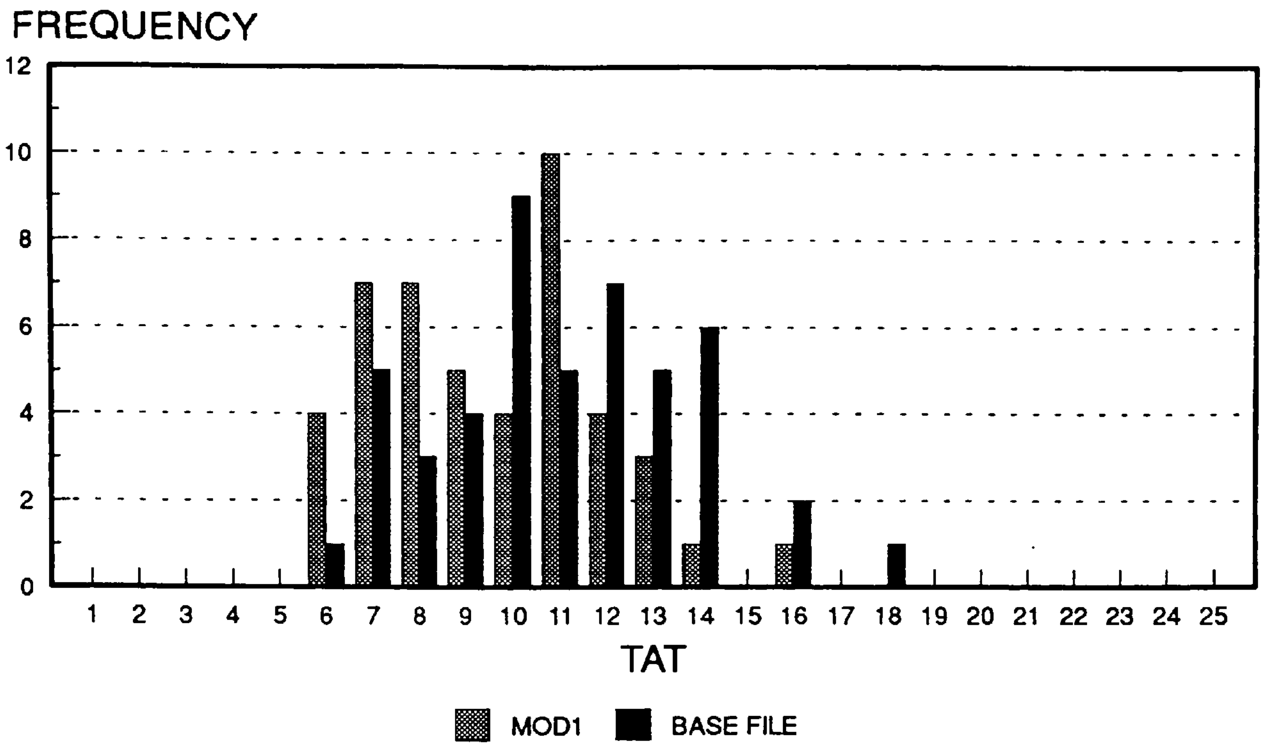
02 MOD1 REMOVAL OF ELECTRO BOOTH



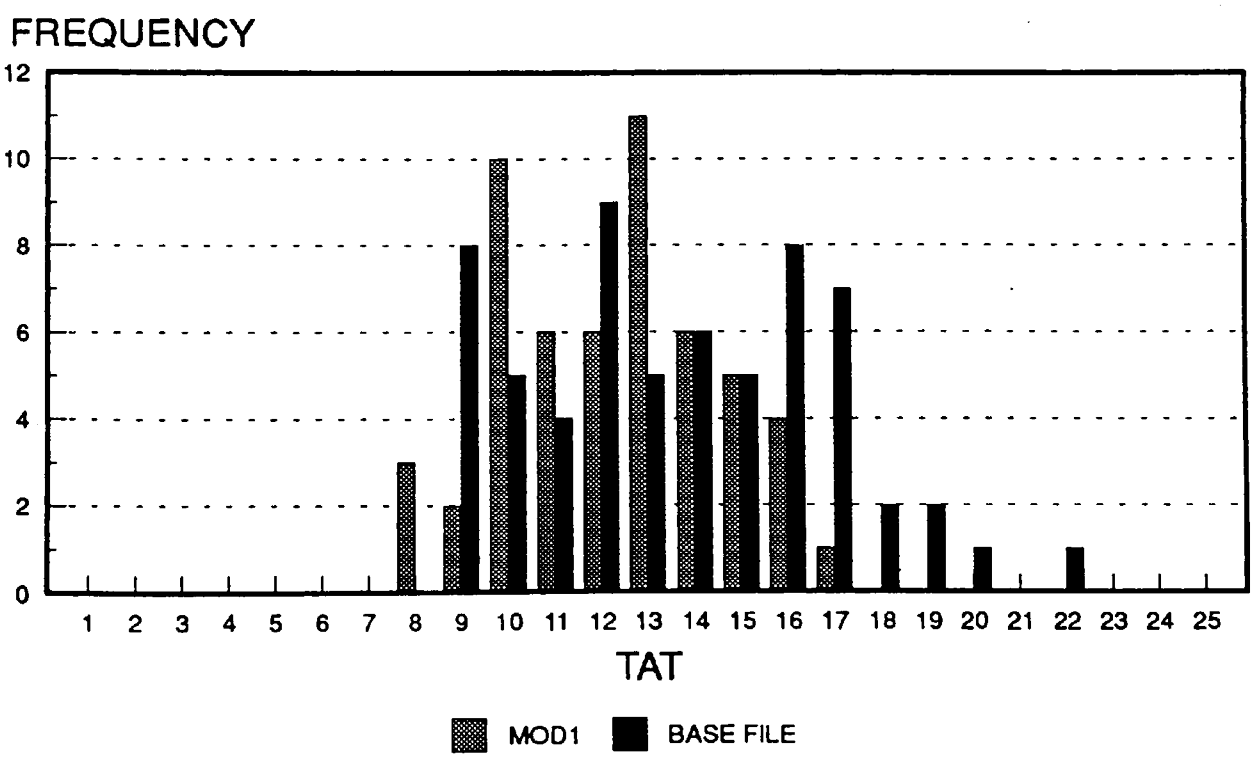

01 MOD1 REMOVAL OF ELECTRO BOOTH
FREQUENCY
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
TAT
MOD1
BASE FILE


02 MOD1 REMOVAL OF ELECTRO BOOTH
FREQUENCY
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
TAT
MOD1
BASE FILE

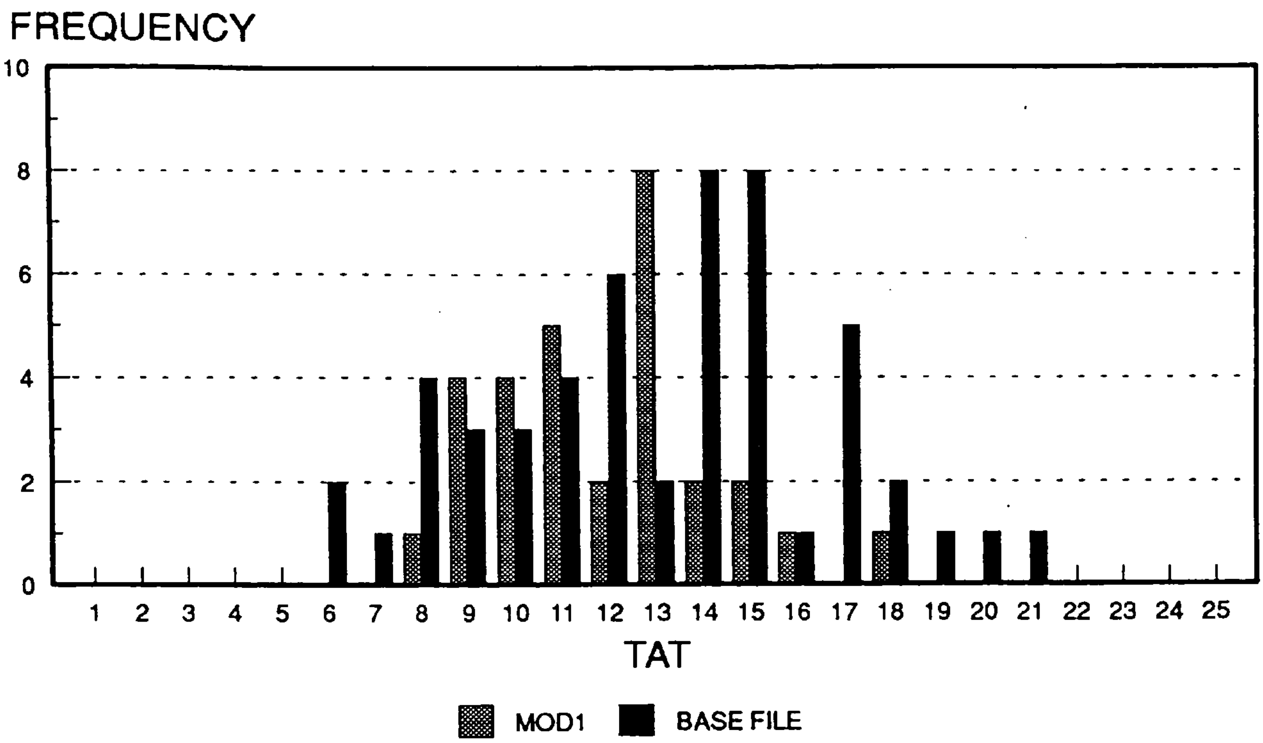
03 MOD1 REMOVAL OF ELECTRO BOOTH



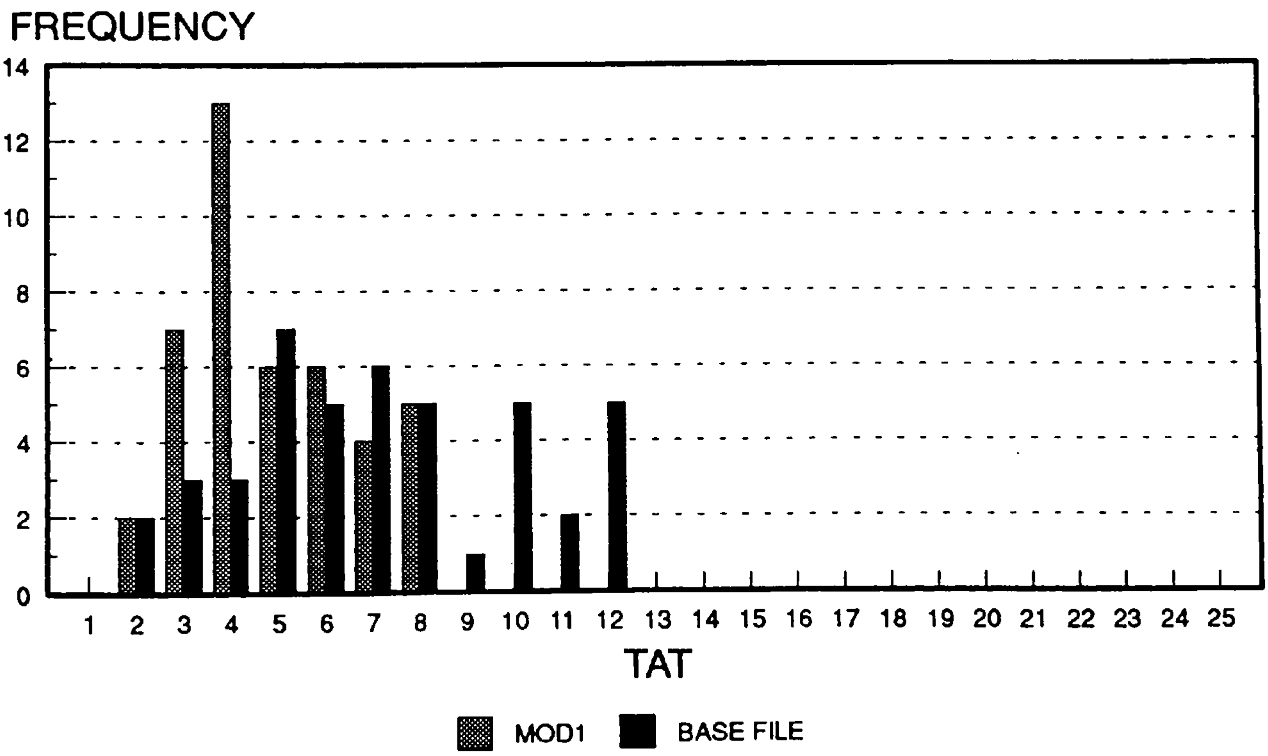
04 MOD1 REMOVAL OF ELECTRO BOOTH



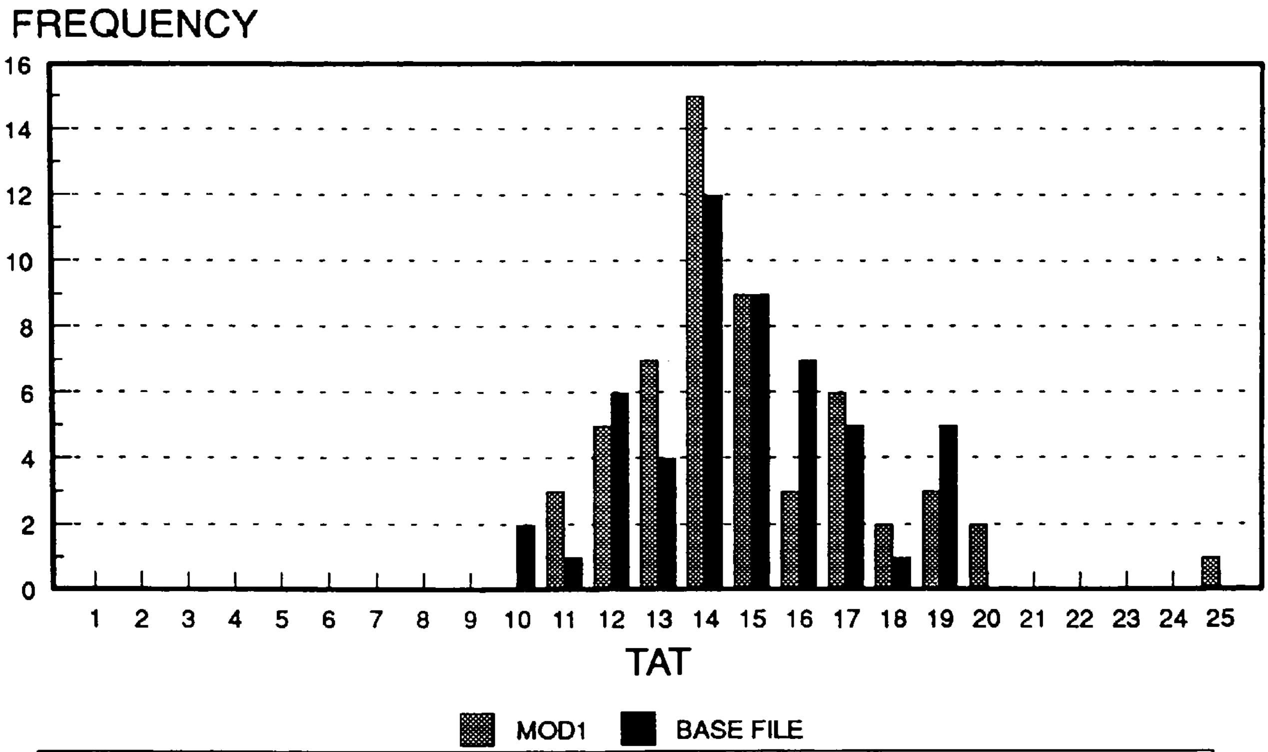
05 MOD1 REMOVAL OF ELECTRO BOOTH



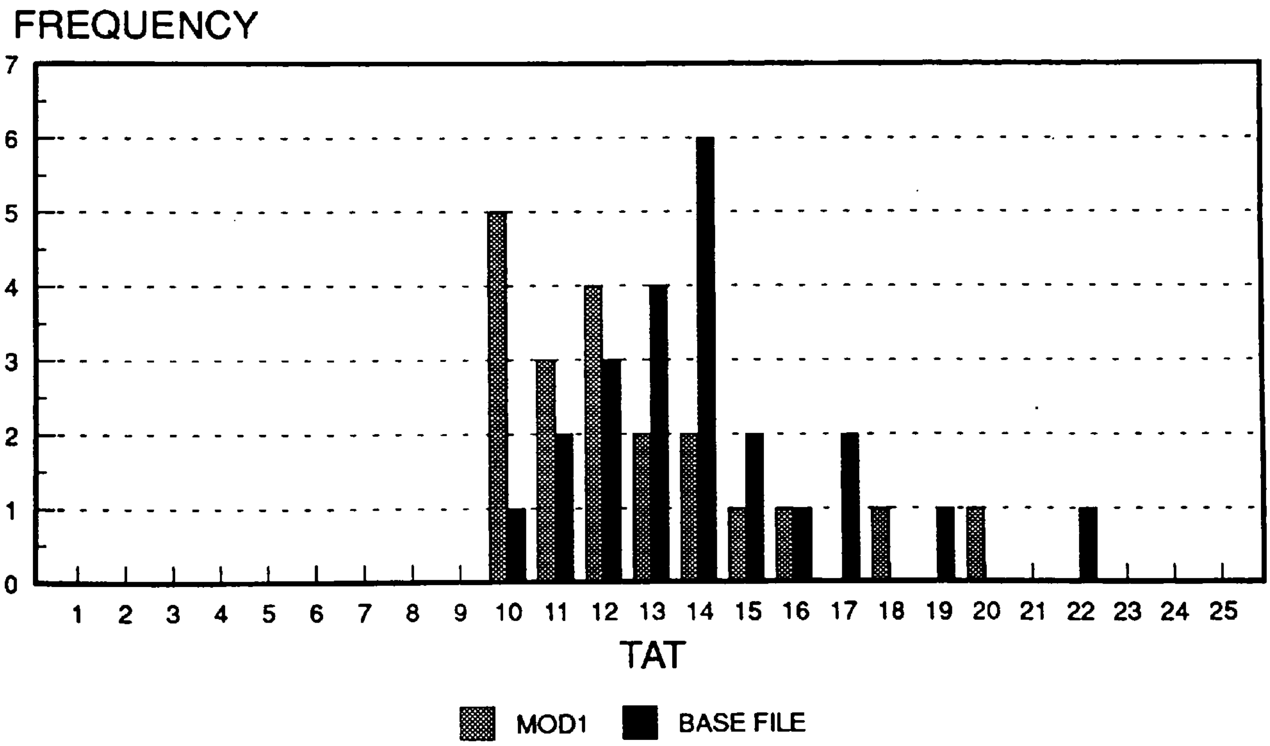
06 MOD1 REMOVAL OF ELECTRO BOOTH



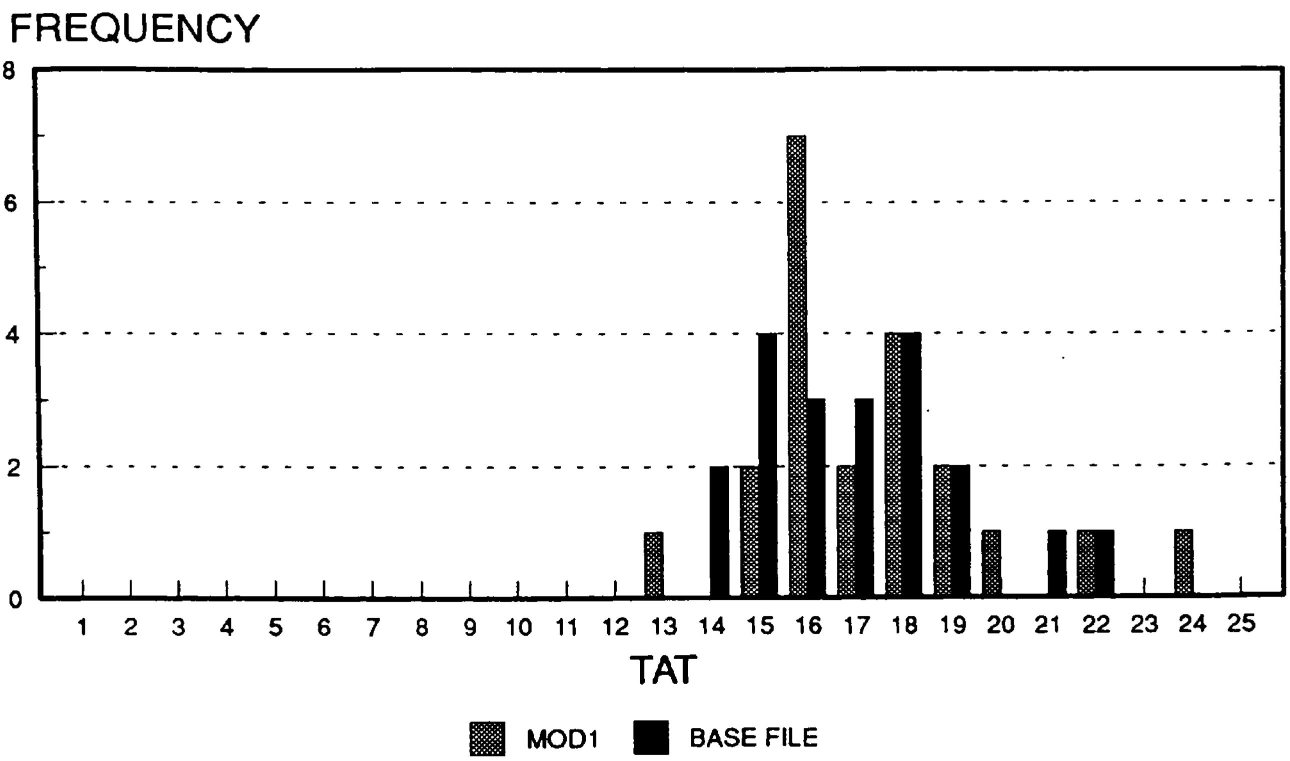
JT9 MOD1 REMOVAL OF ELECTRO BOOTH



JT8 MOD1 REMOVAL OF ELECTRO BOOTH

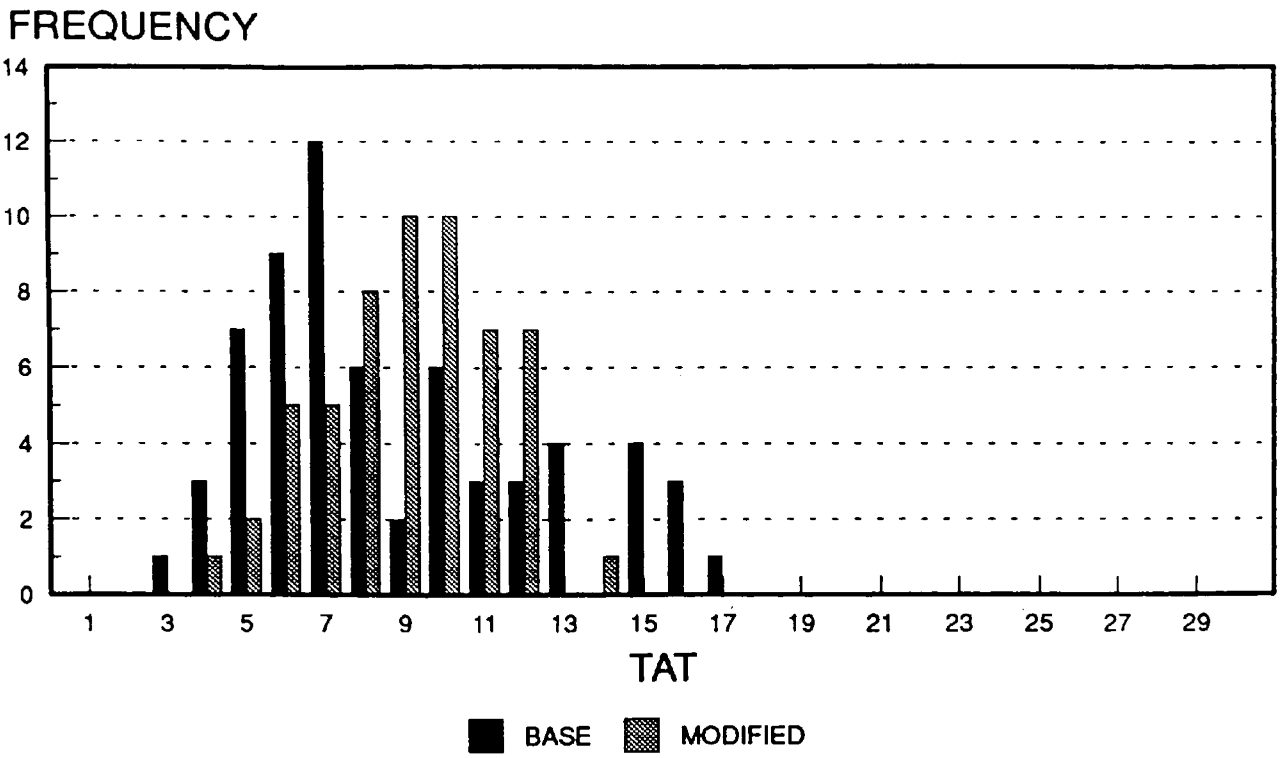


OLY MOD1 REMOVAL OF ELECTRO BOOTH

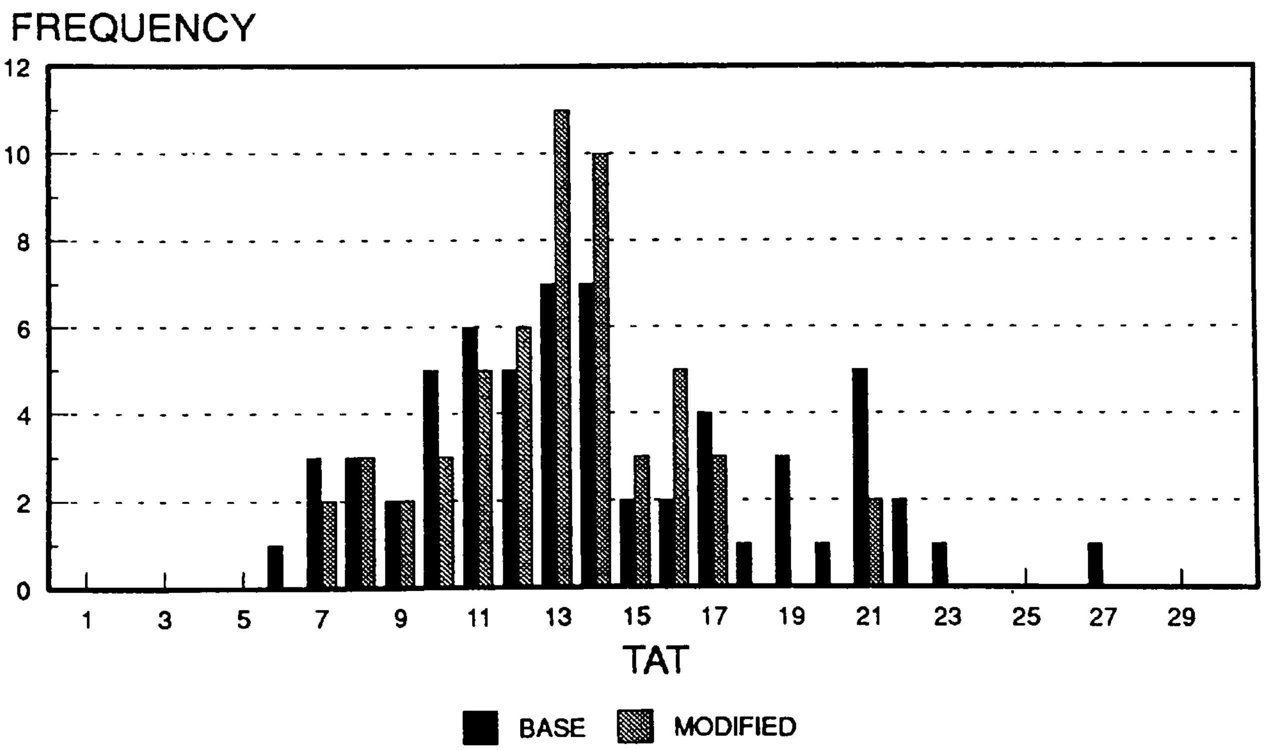


7.2) Implementation of an 04 KANBAN in the strip shop

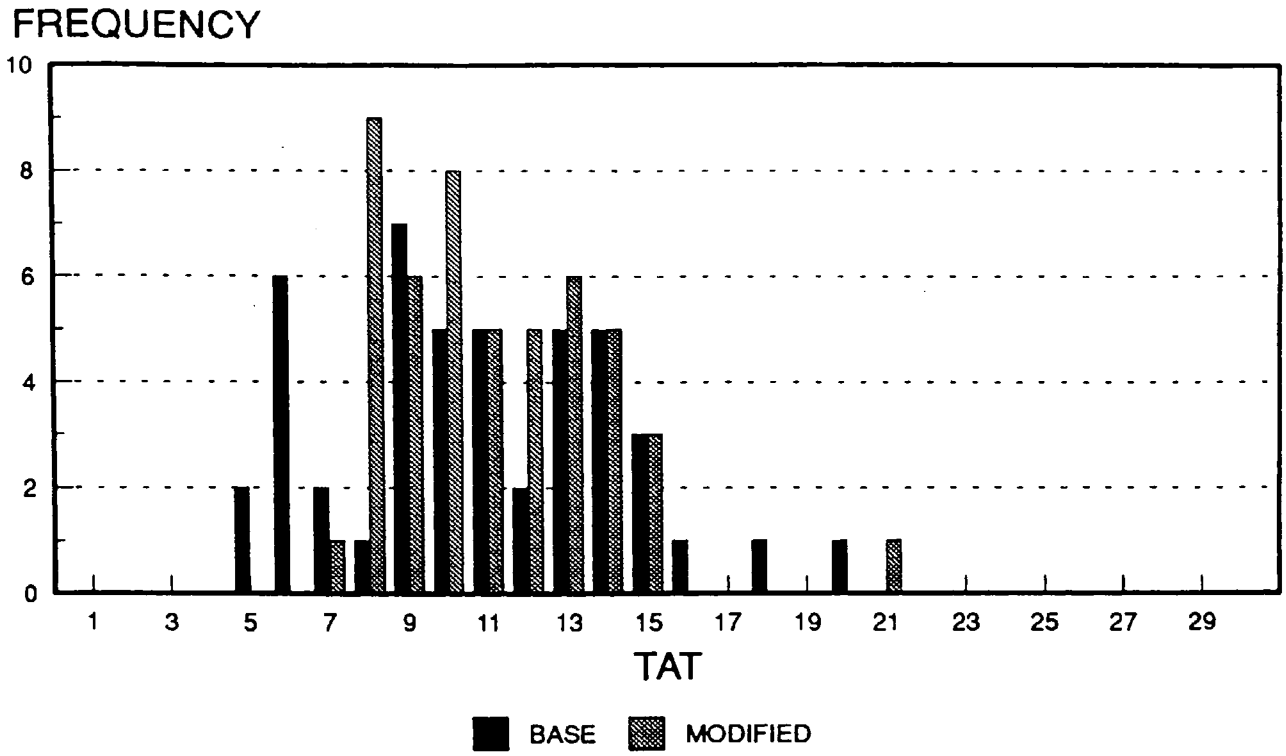
01 - 04 KANBAN SYSTEM IN STRIP SHOP



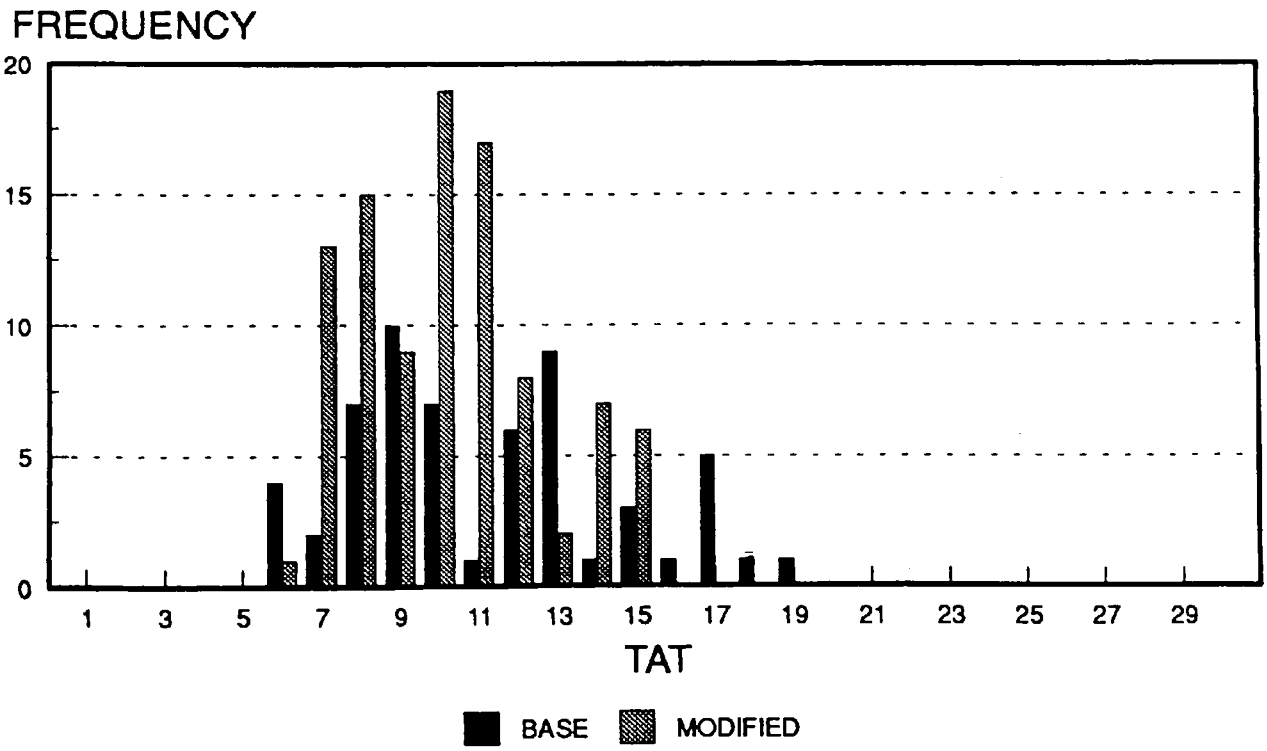
02 - 04 KANBAN SYSTEM IN STRIP SHOP



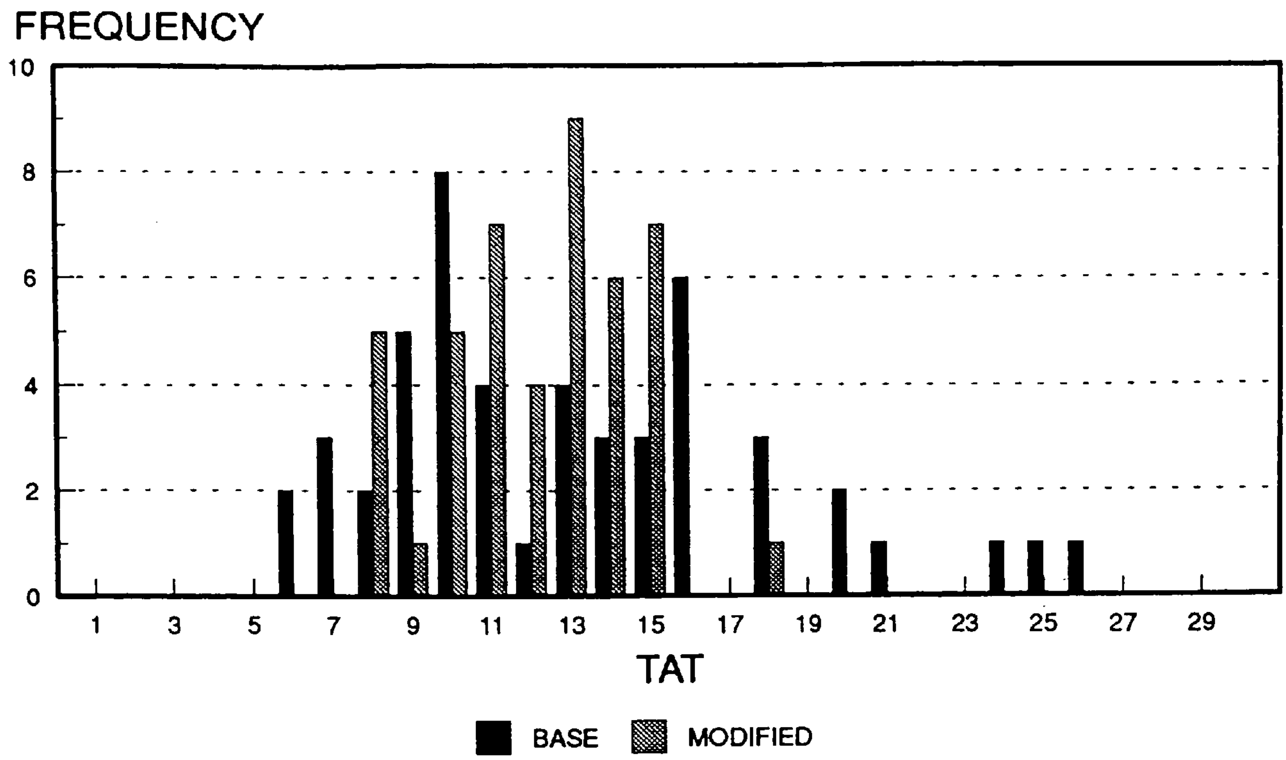
03 - 04 KANBAN SYSTEM IN STRIP SHOP



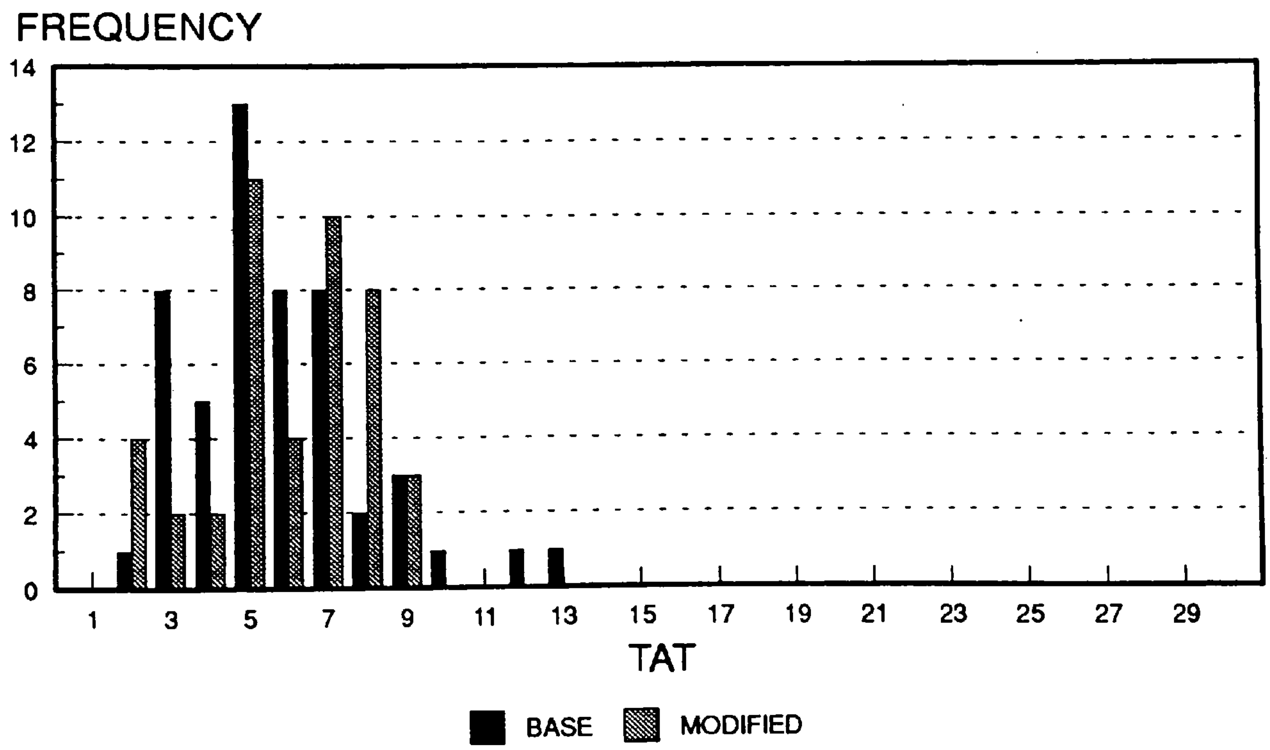
04 - 04 KANBAN SYSTEM IN STRIP SHOP



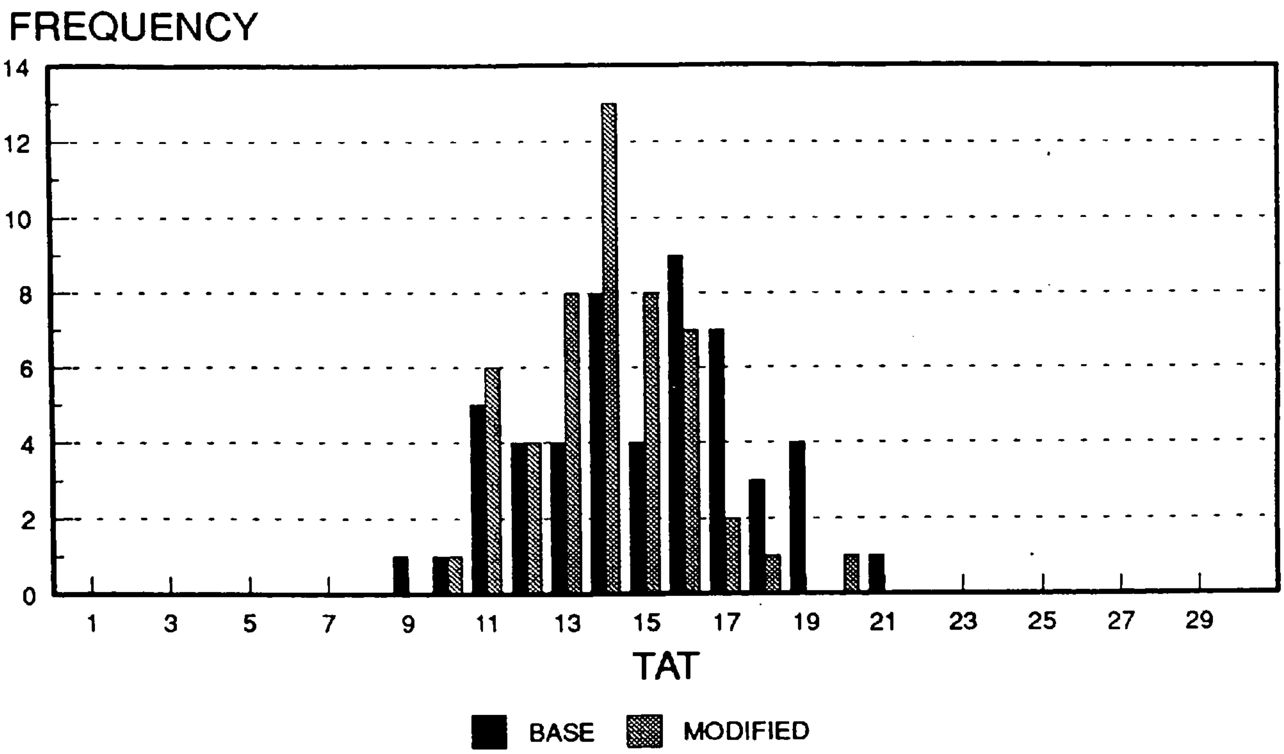
05 - 04 KANBAN SYSTEM IN STRIP SHOP



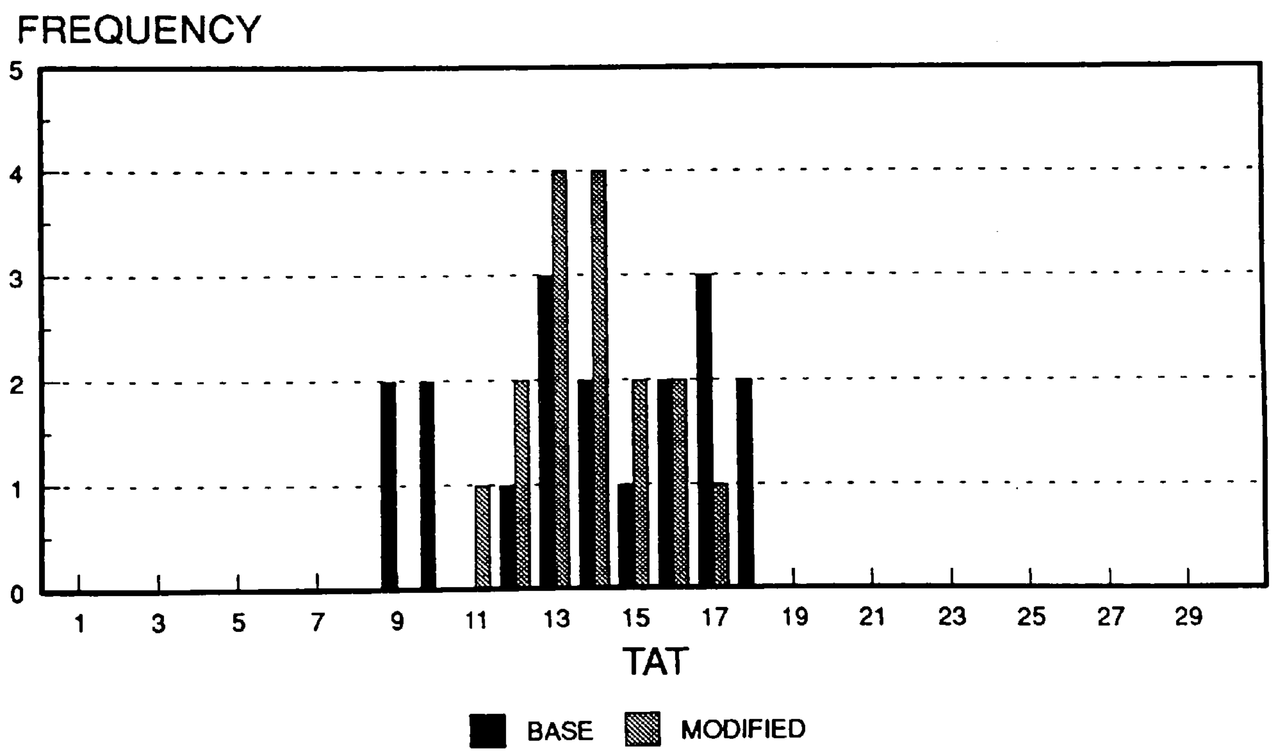
06 - 04 KANBAN SYSTEM IN STRIP SHOP

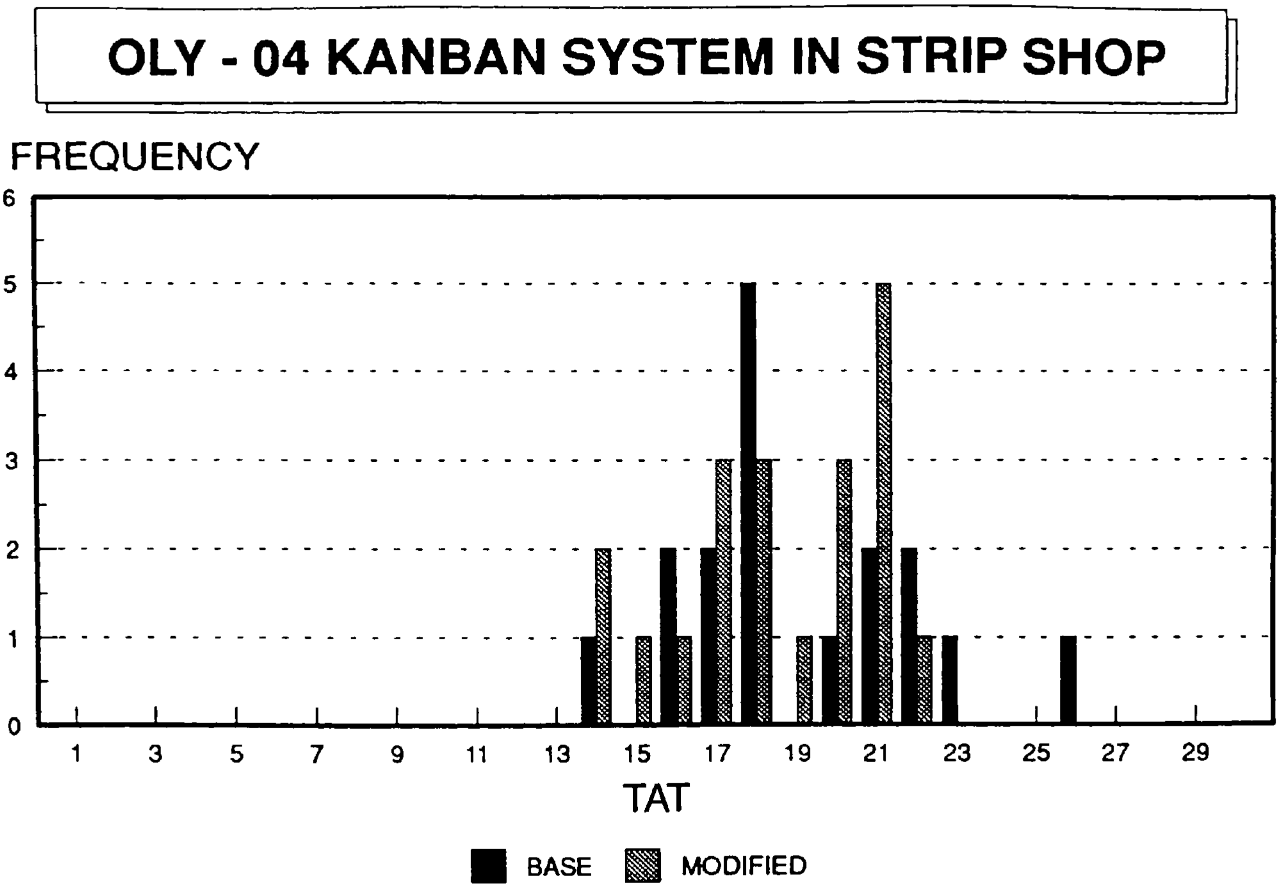


JT9 - 04 KANBAN SYSTEM IN STRIP SHOP



JT8 - 04 KANBAN SYSTEM IN STRIP SHOP

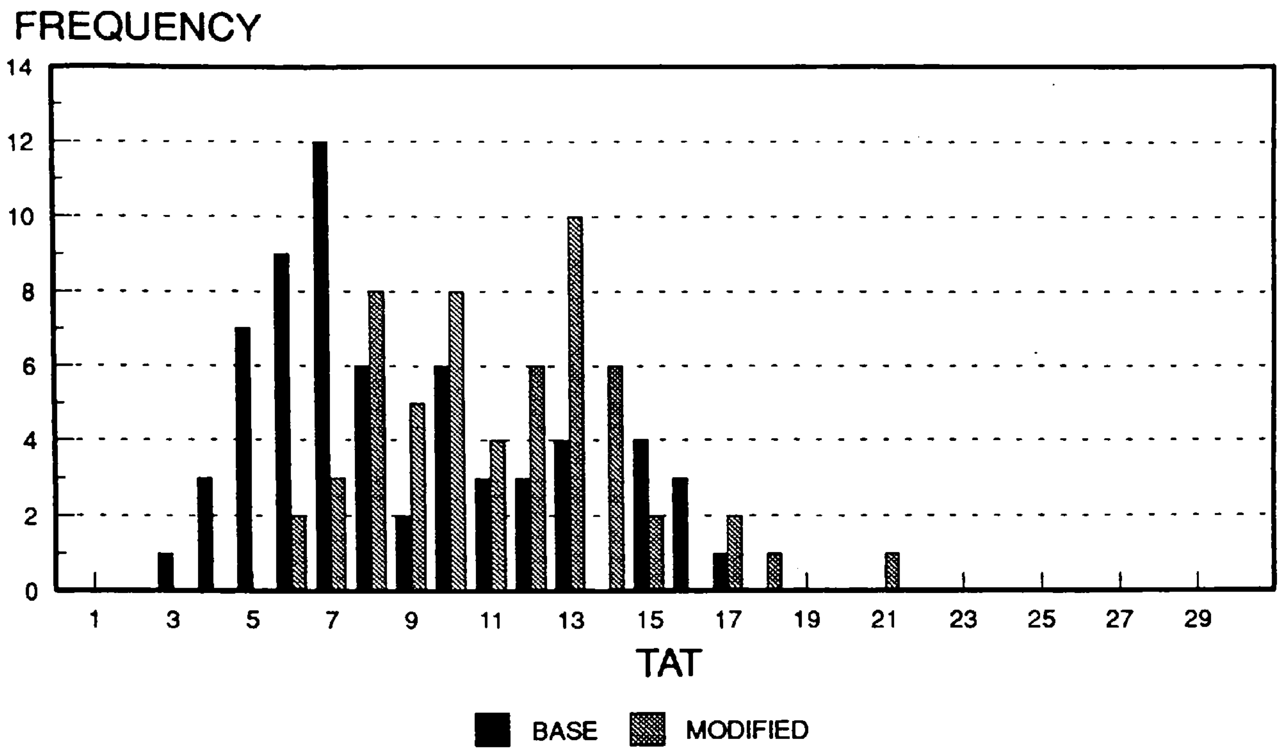




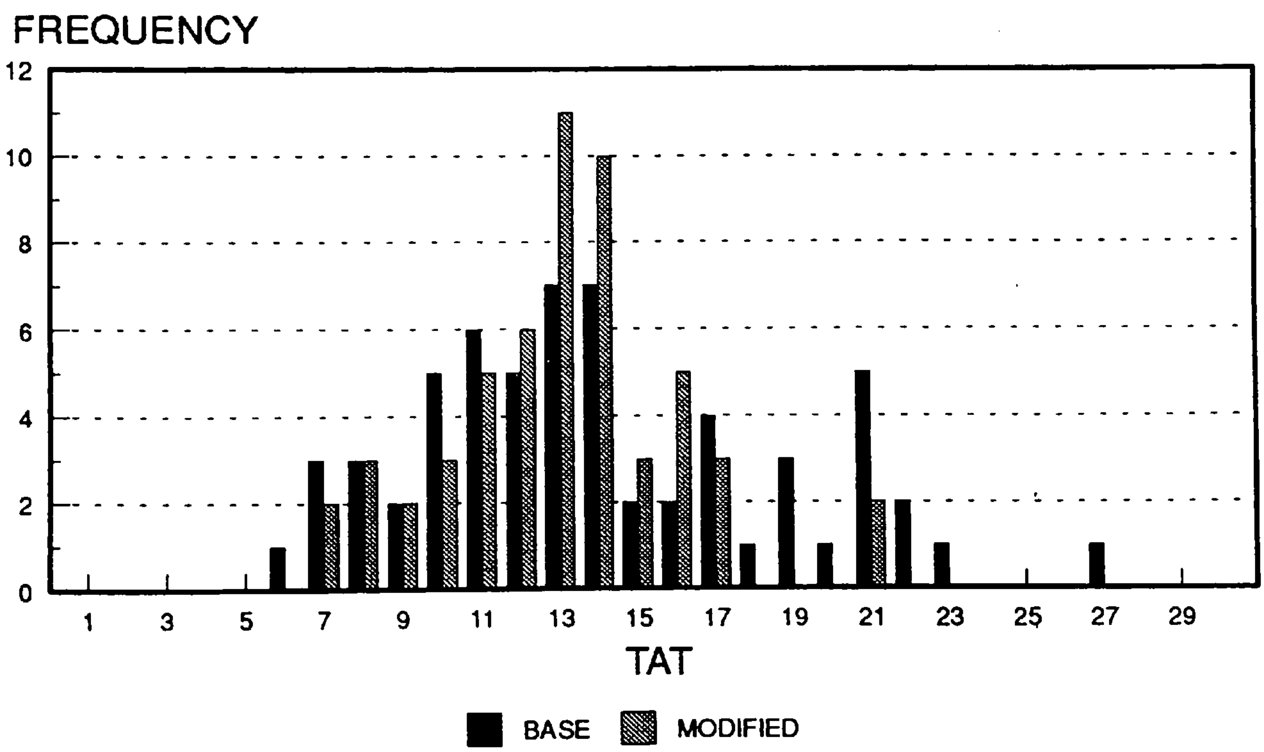
OLY - 04 KANBAN SYSTEM IN STRIP SHOP
FREQUENCY
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
TAT
BASE
MODIFIED

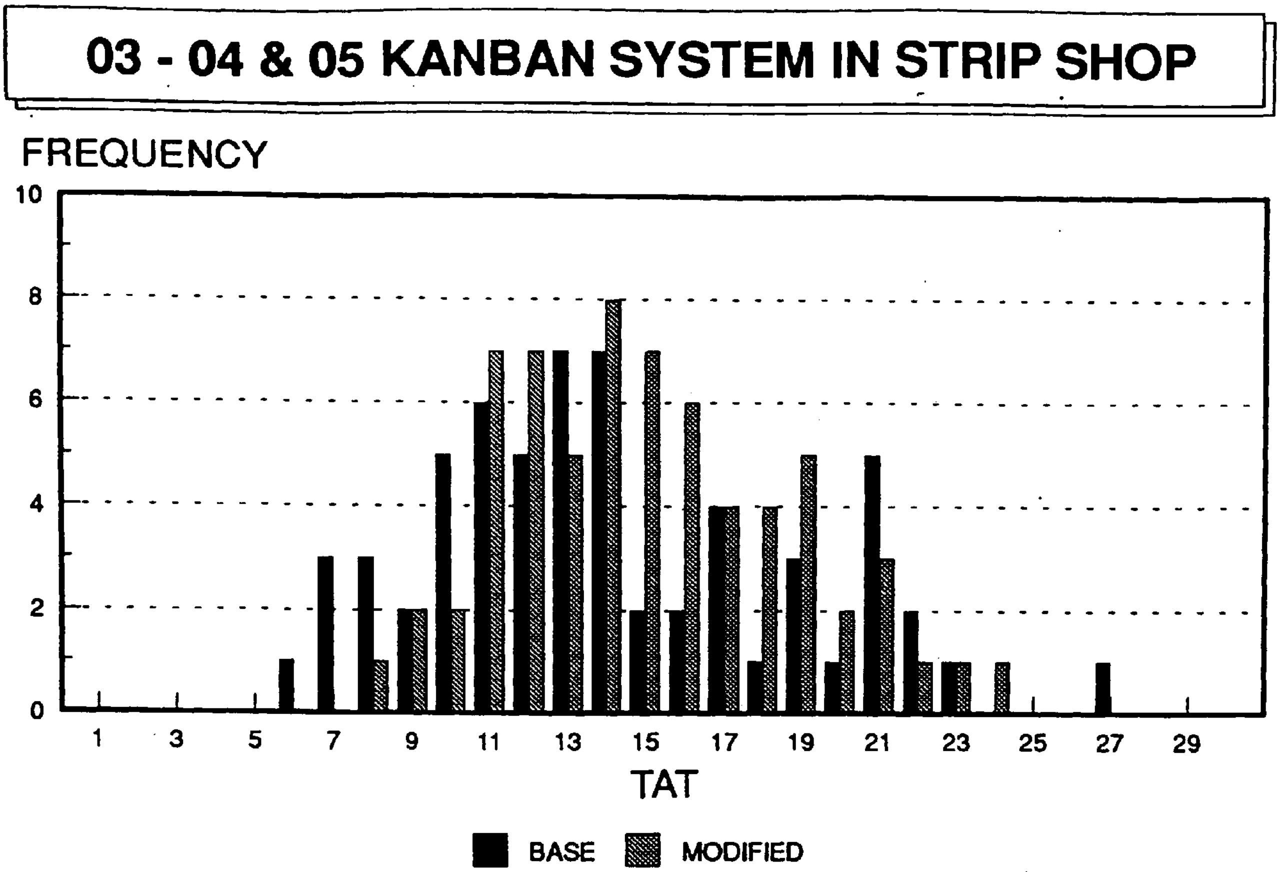
7.3) Implementation of an 04 and 05 KANBAN in the strip shop

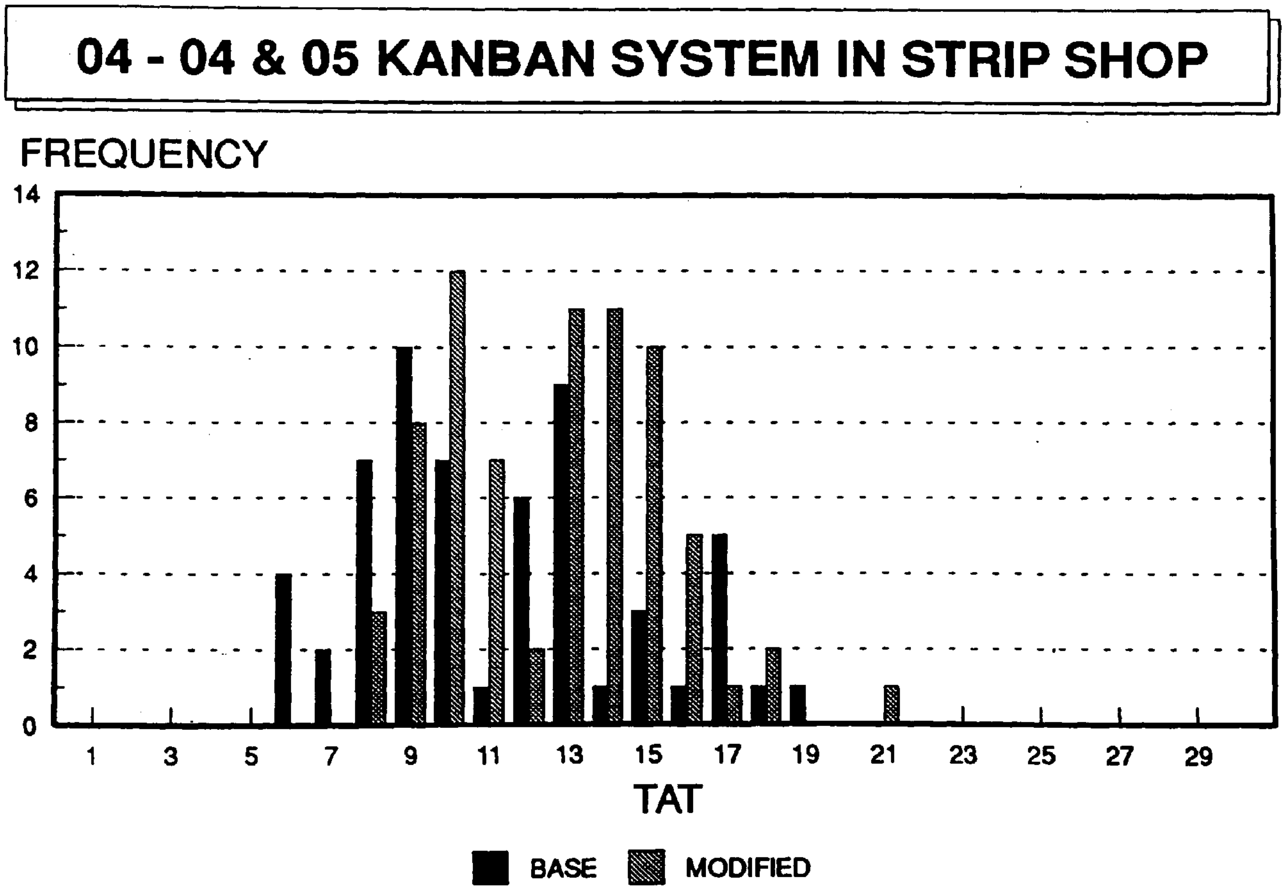
01 - 04 & 05 KANBAN SYSTEM IN STRIP SHOP



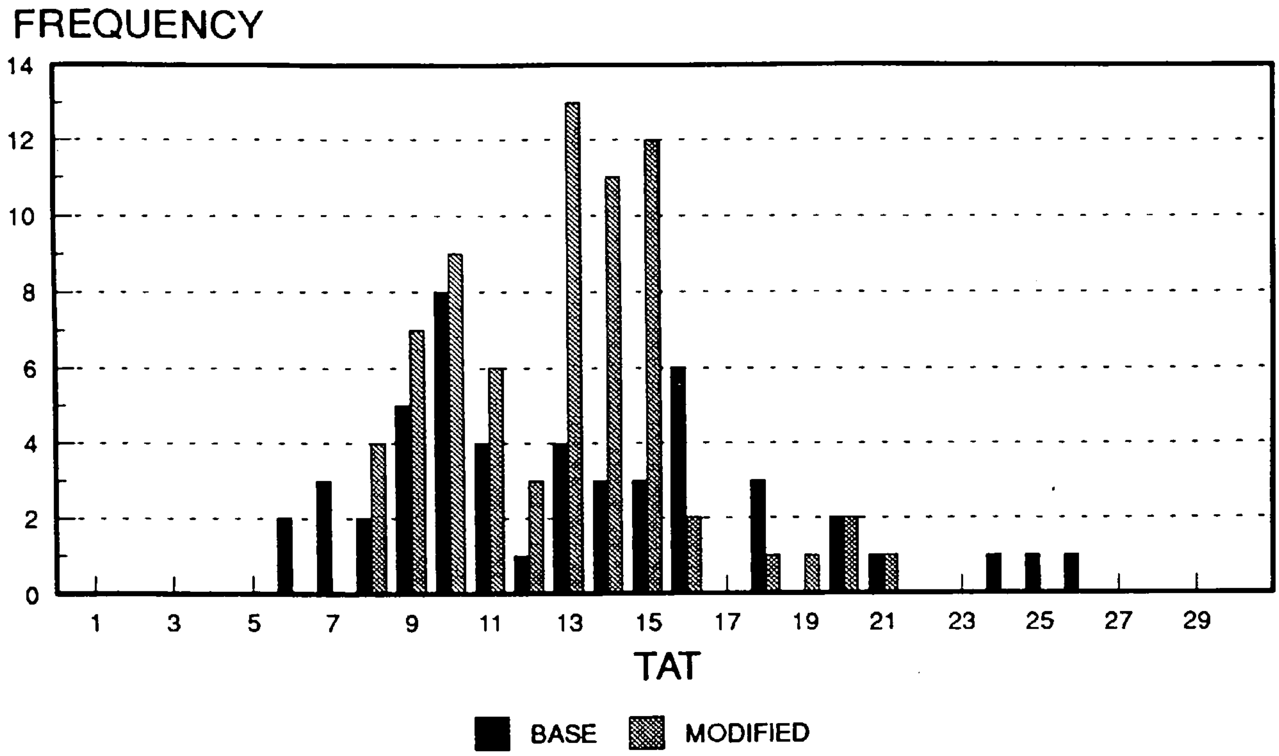
02 - 04 KANBAN SYSTEM IN STRIP SHOP



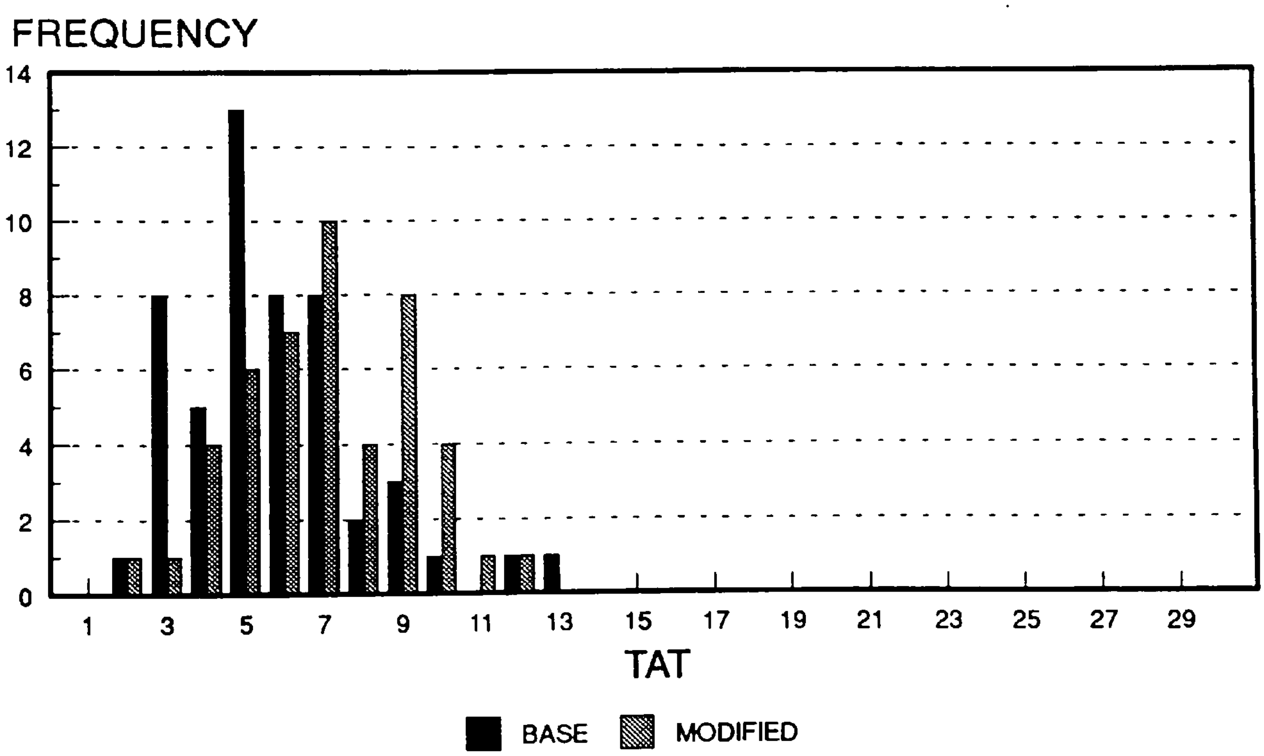

03 - 04 & 05 KANBAN SYSTEM IN STRIP SHOP
FREQUENCY
10
8
6
4
2
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
TAT
BASE
MODIFIED


04 - 04 & 05 KANBAN SYSTEM IN STRIP SHOP
FREQUENCY
14
12
10
8
6
4
2
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
TAT
BASE
MODIFIED

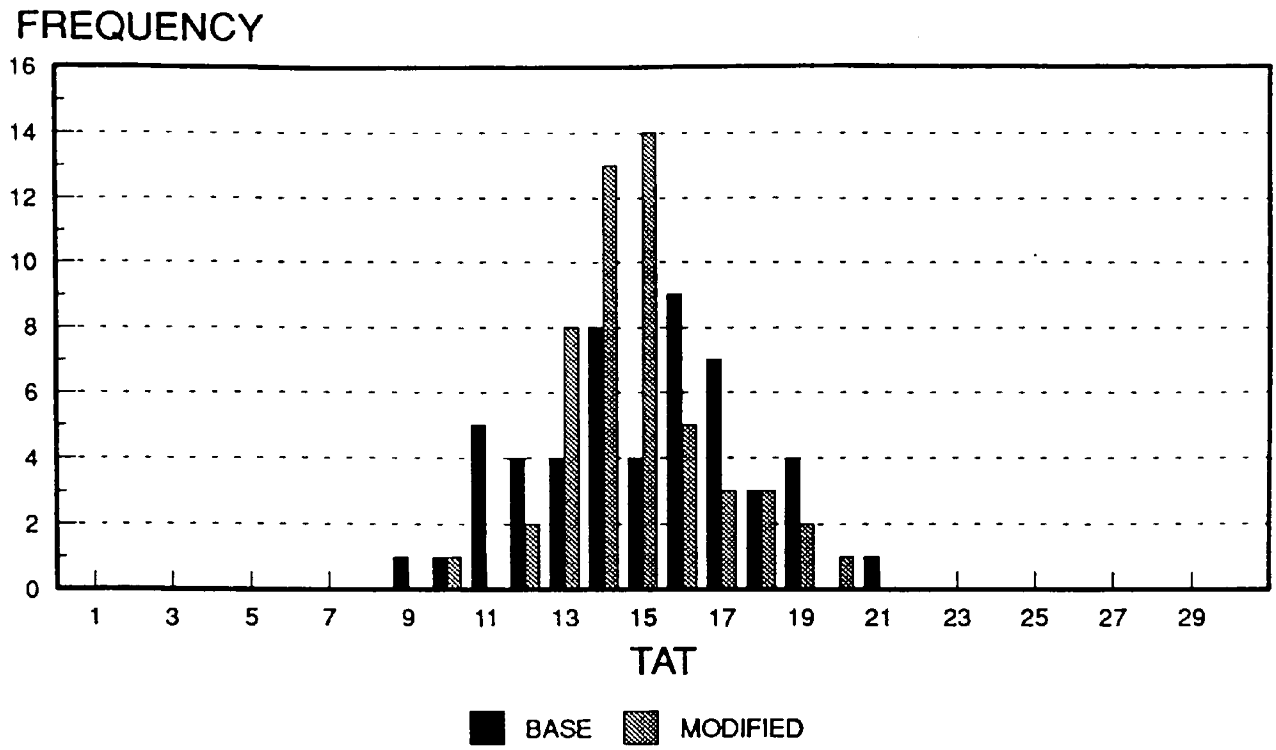
05 - 04 & 05 KANBAN SYSTEM IN STRIP SHOP



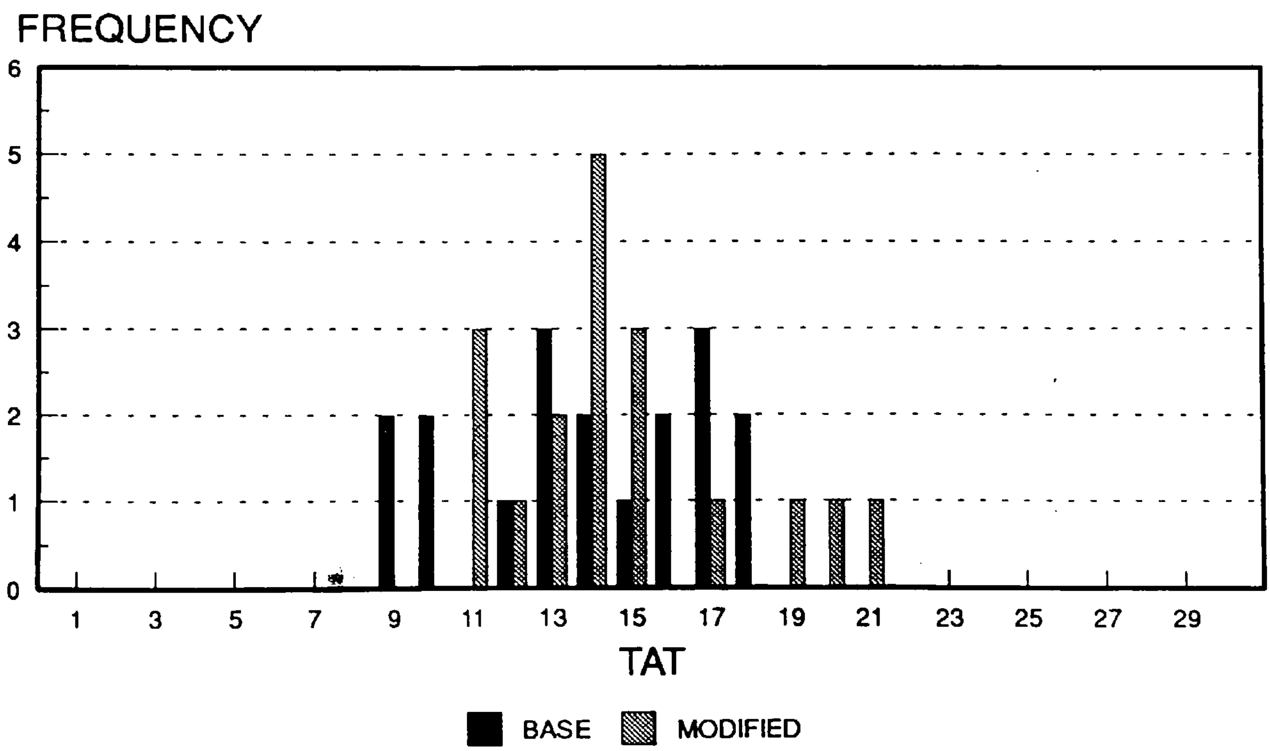
06 - 04 & 05 KANBAN SYSTEM IN STRIP SHOP



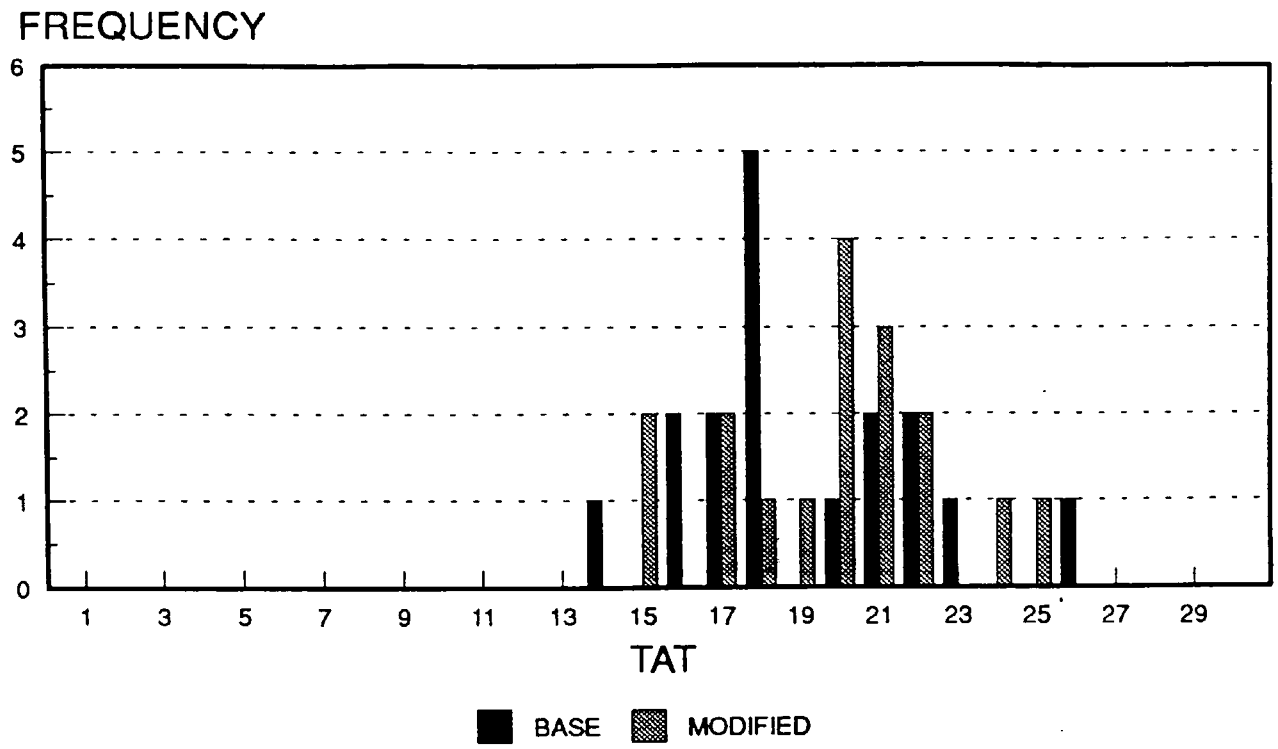
JT9 - 04 & 05 KANBAN SYSTEM IN STRIP SHOP



JT8 - 04 & 05 KANBAN SYSTEM IN STRIP SHOP

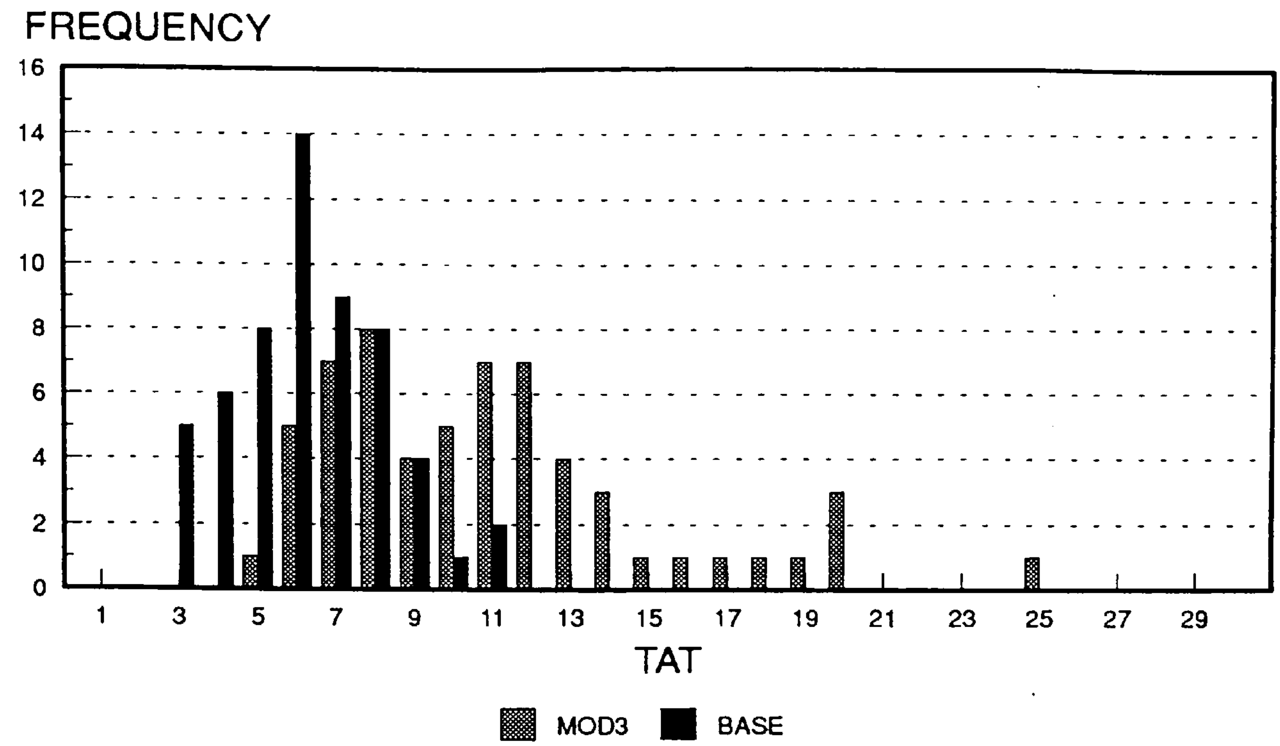


OLY - 04 & 05 KANBAN SYSTEM IN STRIP SHOP

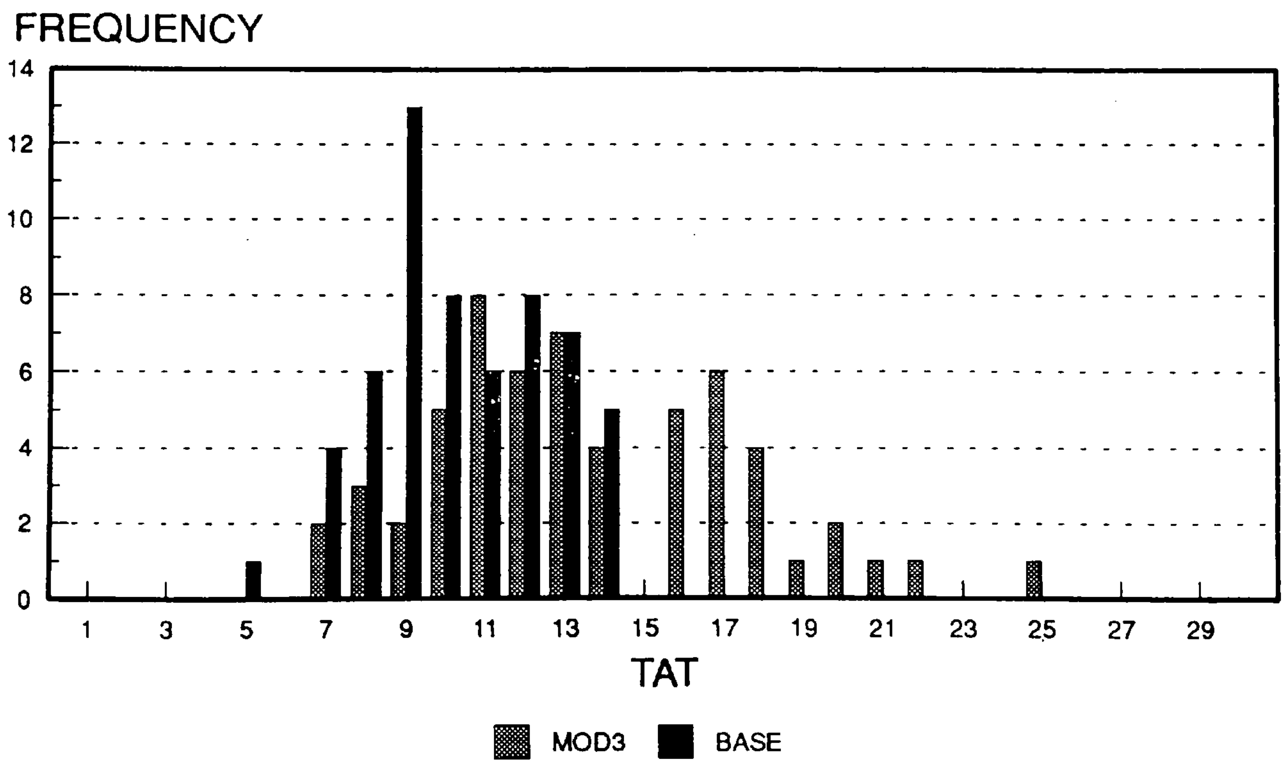


7.4) Movement of one nightshift worker from strip to detail inspection

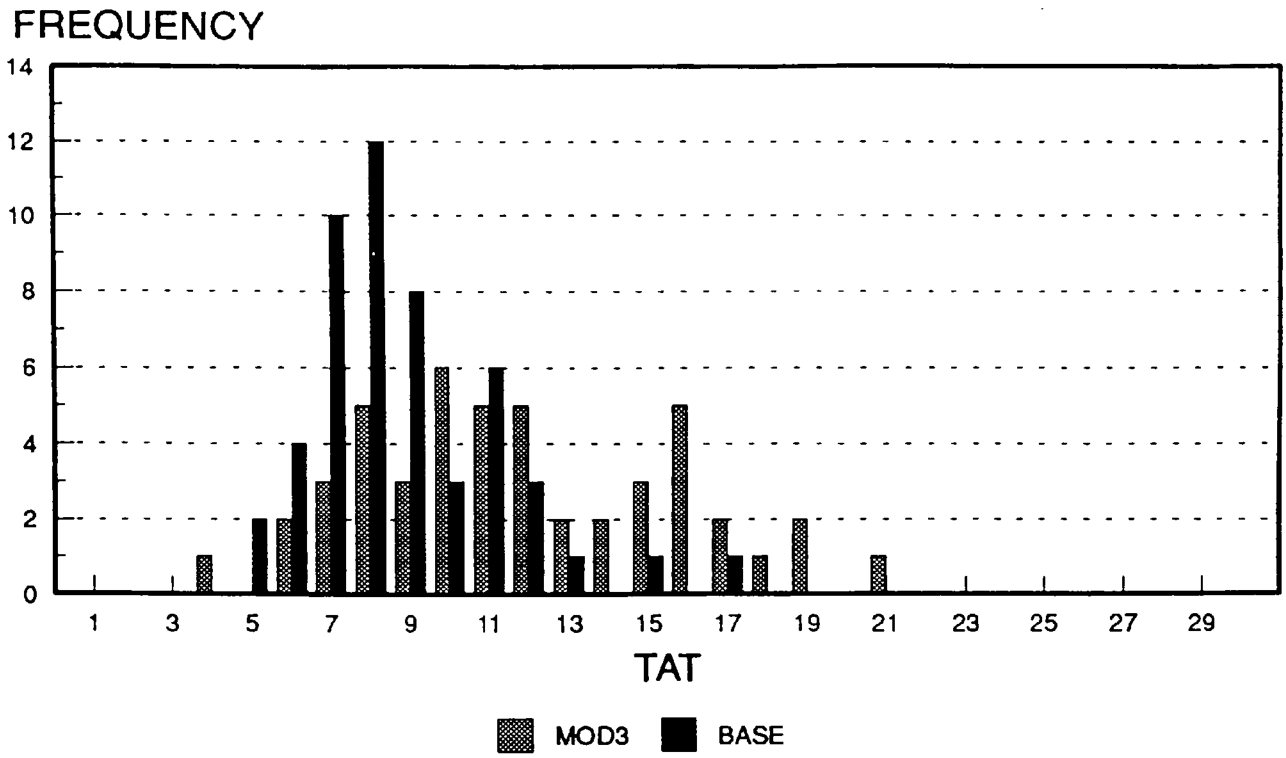
01 NIGHT INSPECTION OF 04 & 05 MODULES



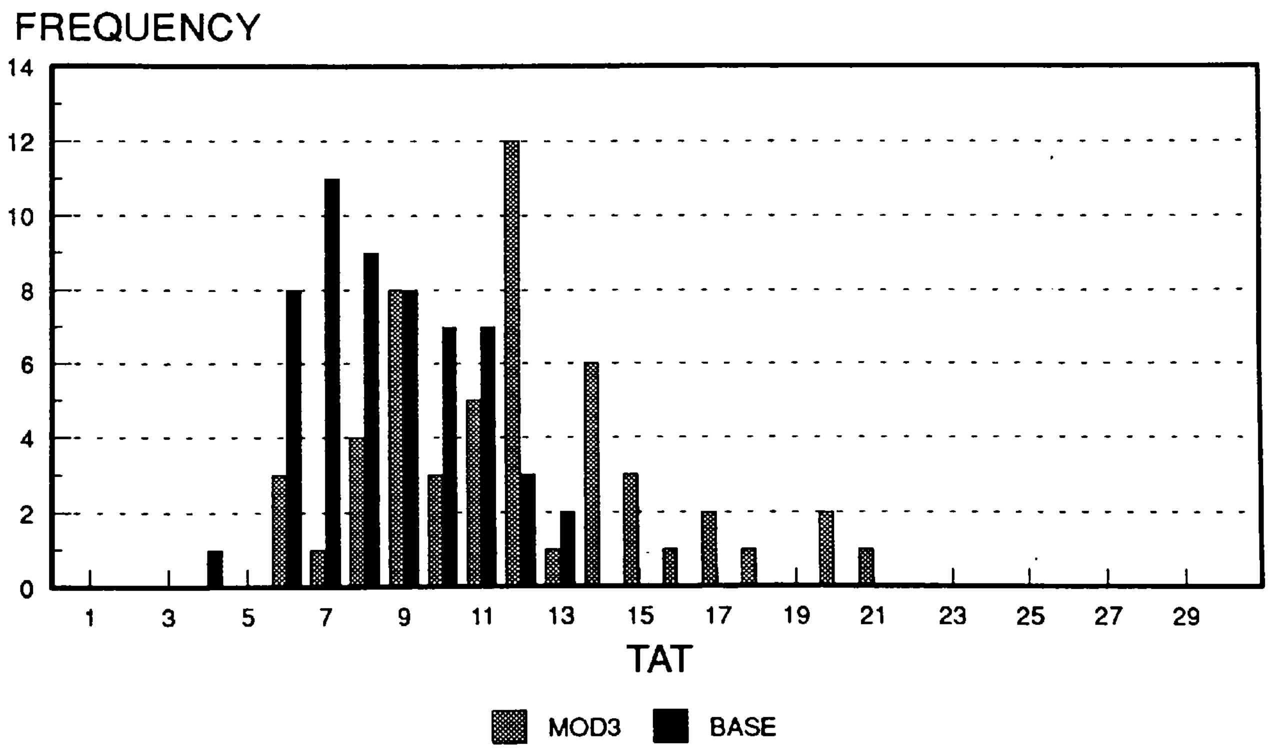
02 NIGHT INSPECTION OF 04 & 05 MODULES



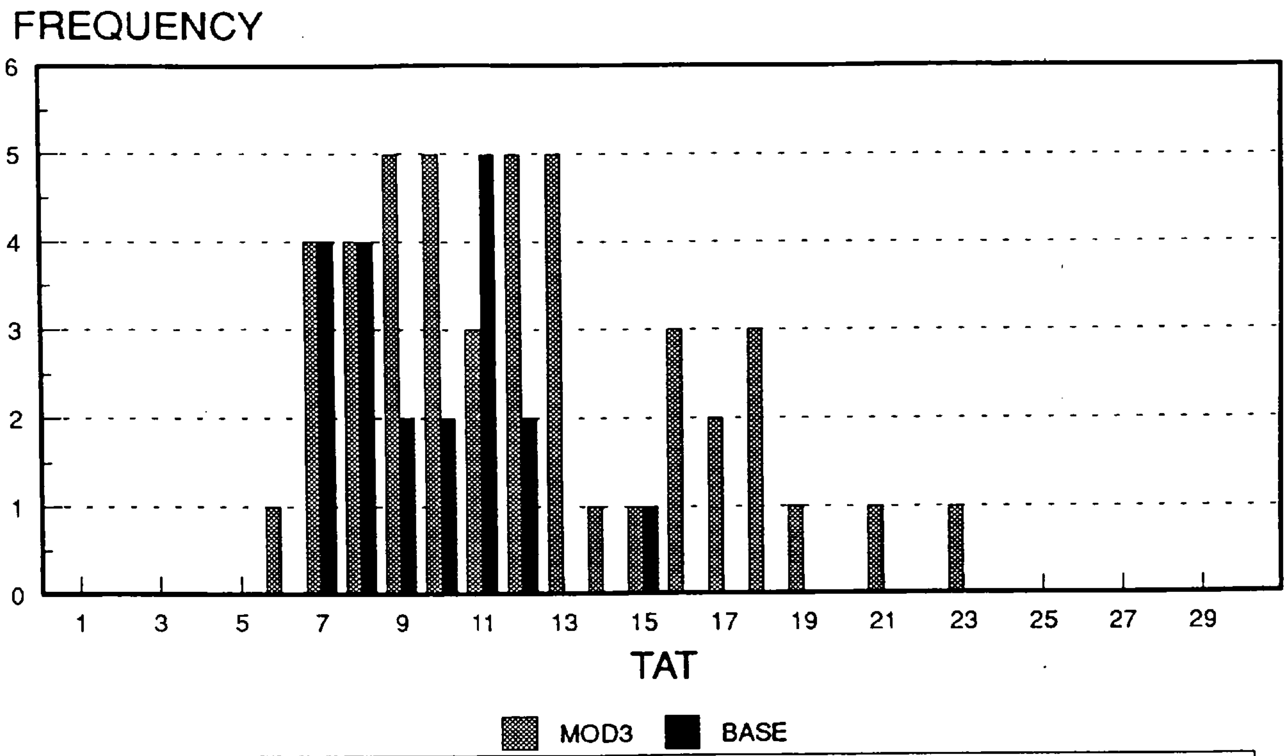
03 NIGHT INSPECTION OF 04 & 05 MODULES



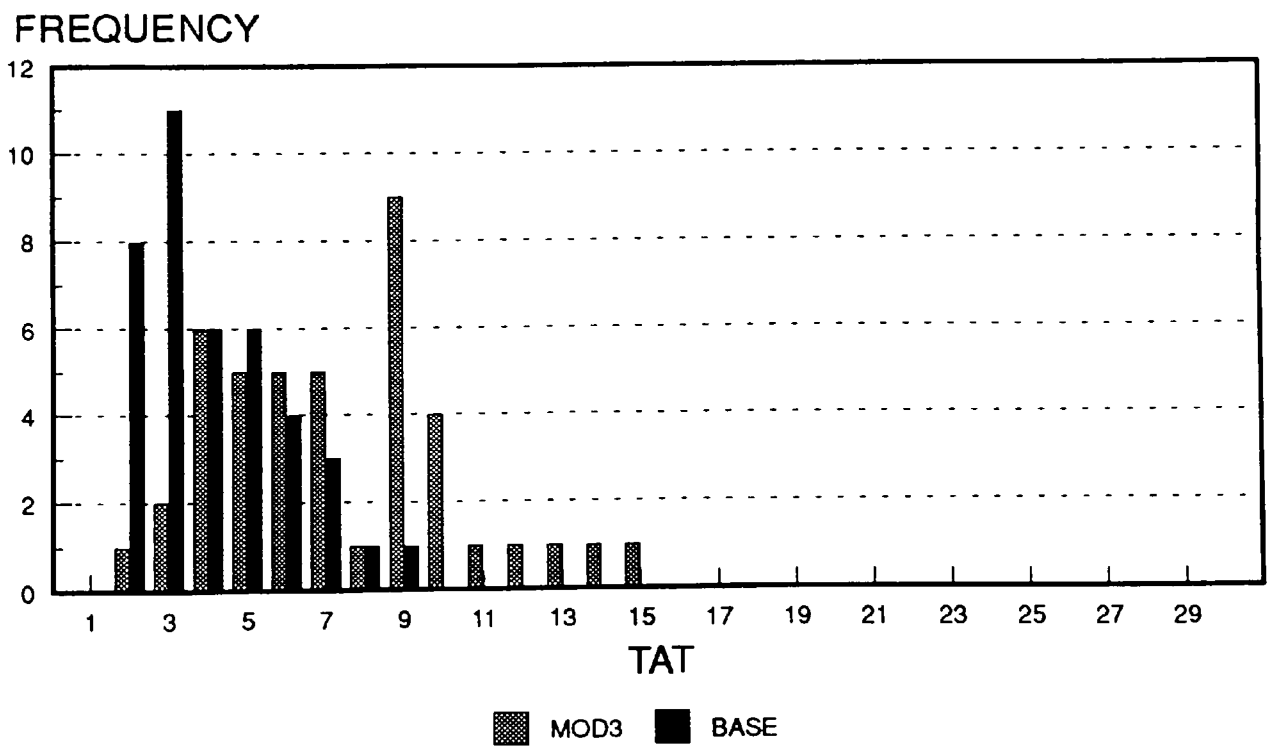
04 NIGHT INSPECTION OF 04 & 05 MODULES



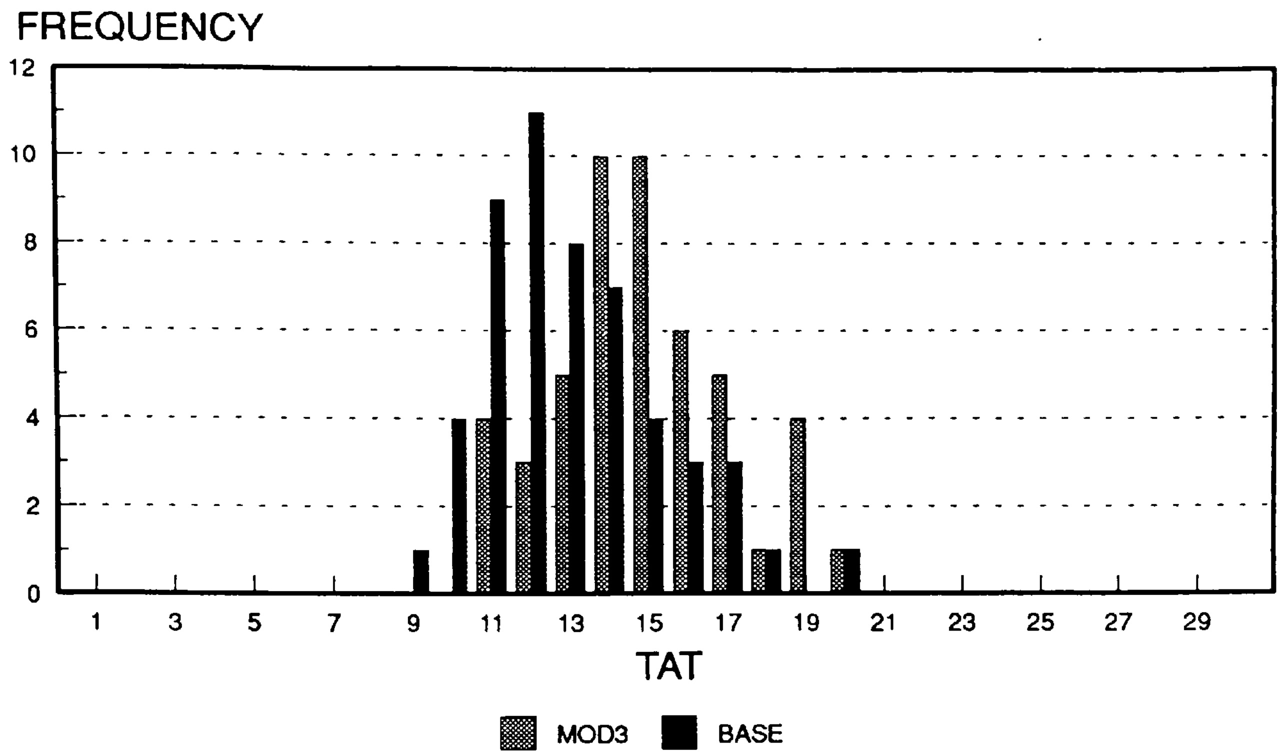
05 NIGHT INSPECTION OF 04 & 05 MODULES



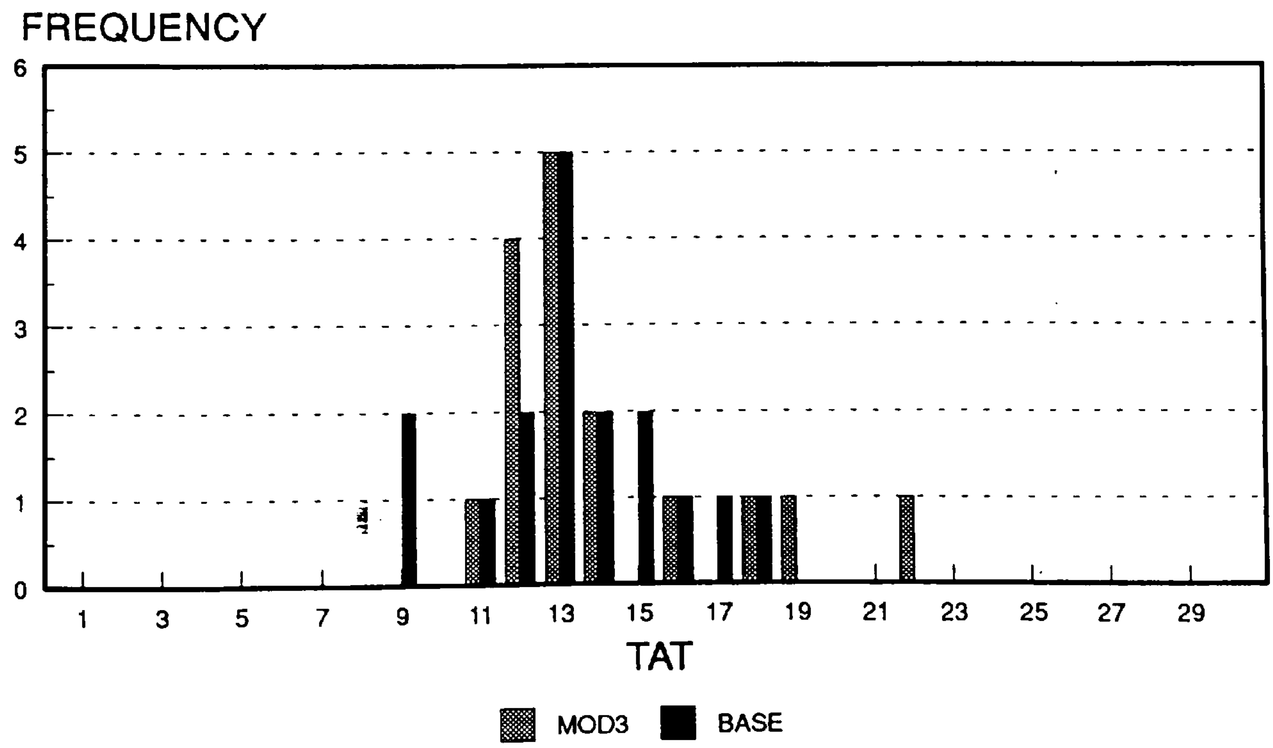
06 NIGHT INSPECTION OF 04 & 05 MODULES

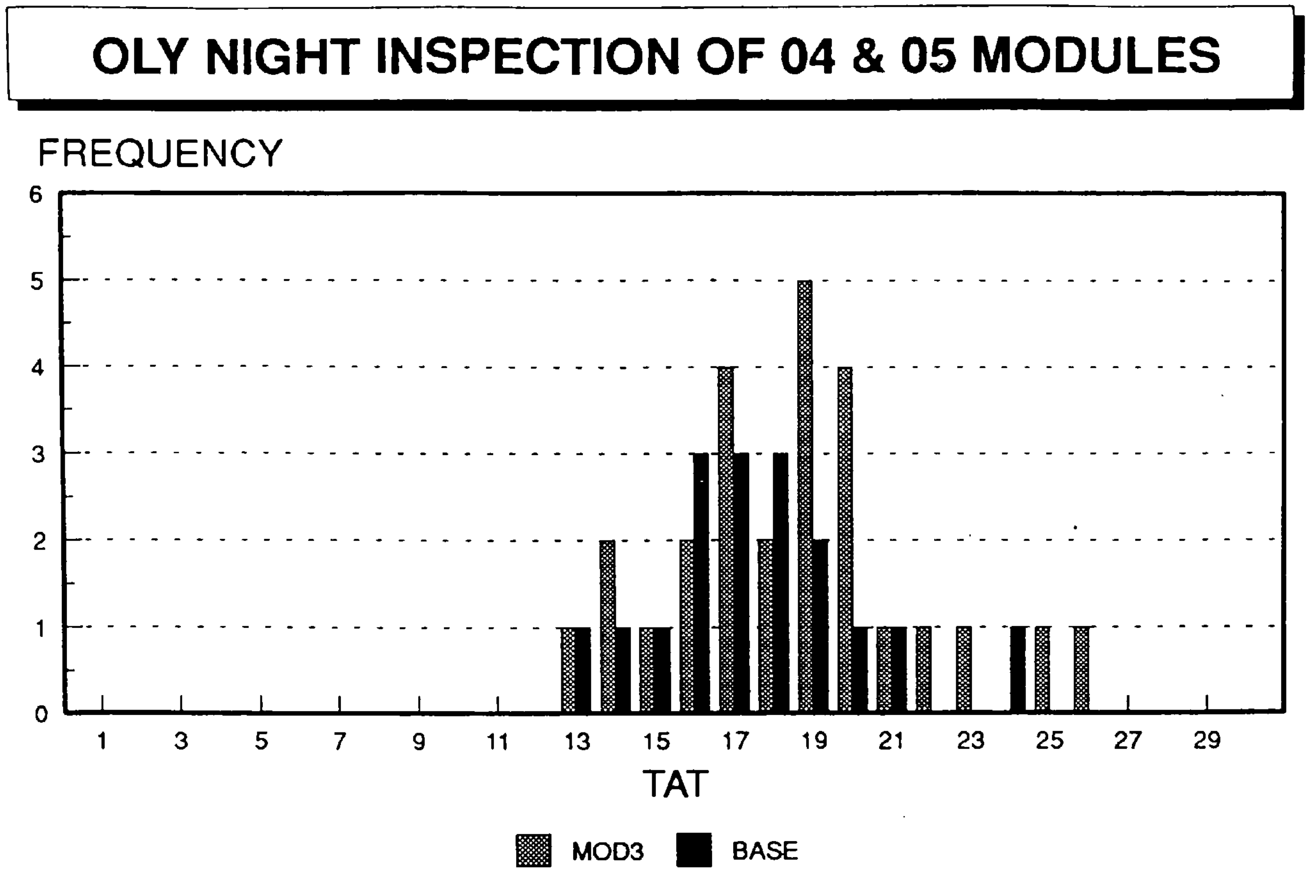


JT9 NIGHT INSPECTION OF 04 & 05 MODULES



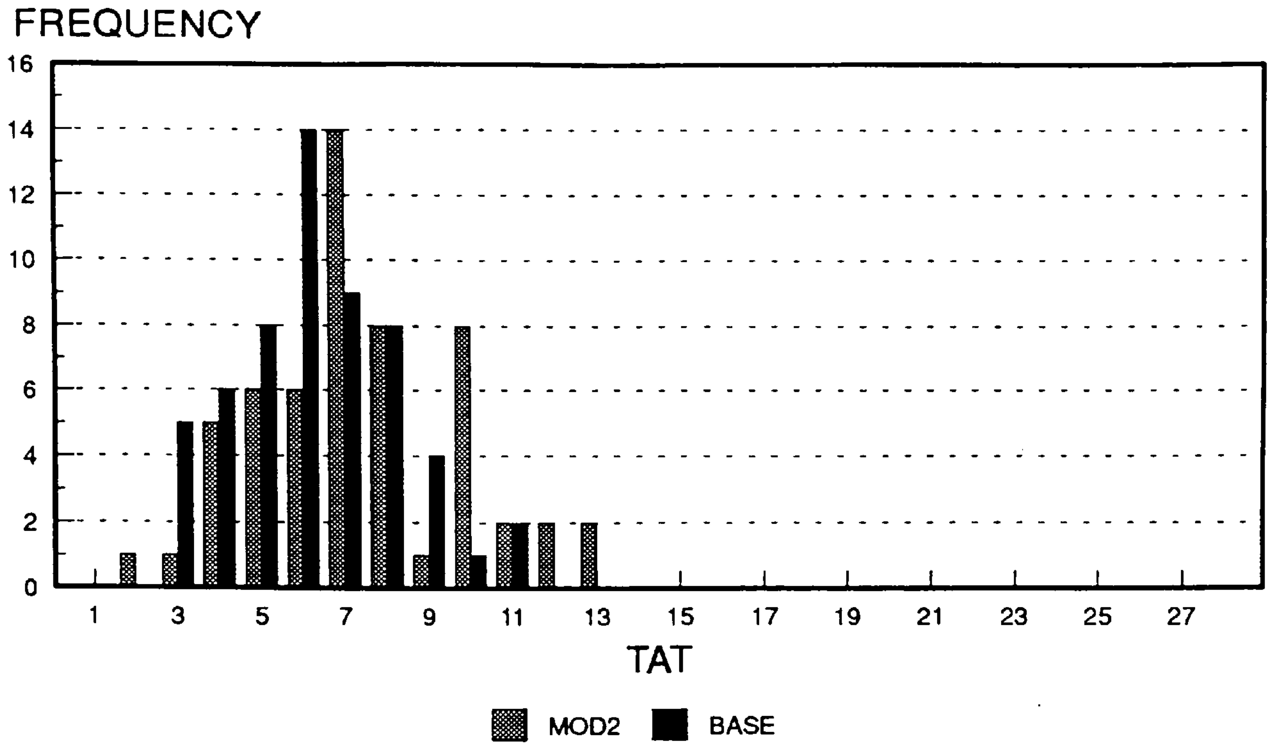
JT8 NIGHT INSPECTION OF 04 & 05 MODULES



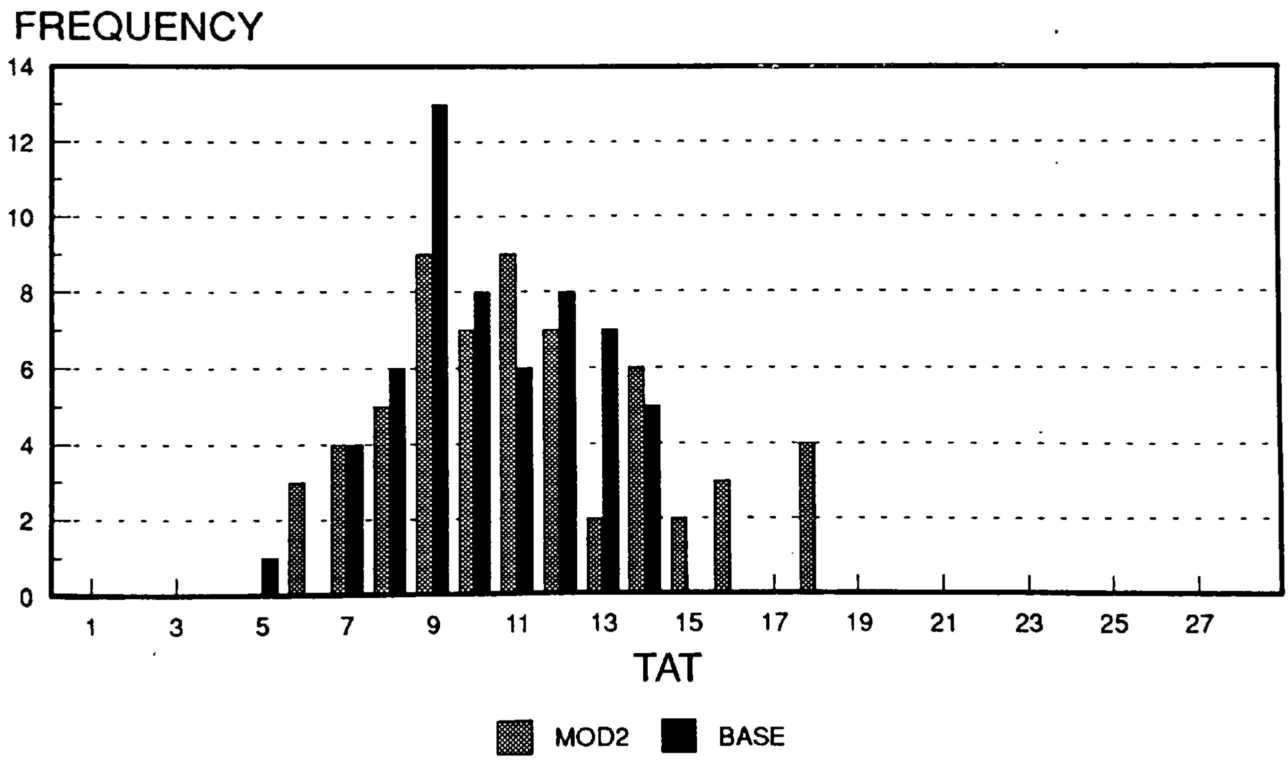

OLY NIGHT INSPECTION OF 04 & 05 MODULES
FREQUENCY
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
TAT
MOD3
BASE

7.5) Stripshop nightshift training on Olympus engine

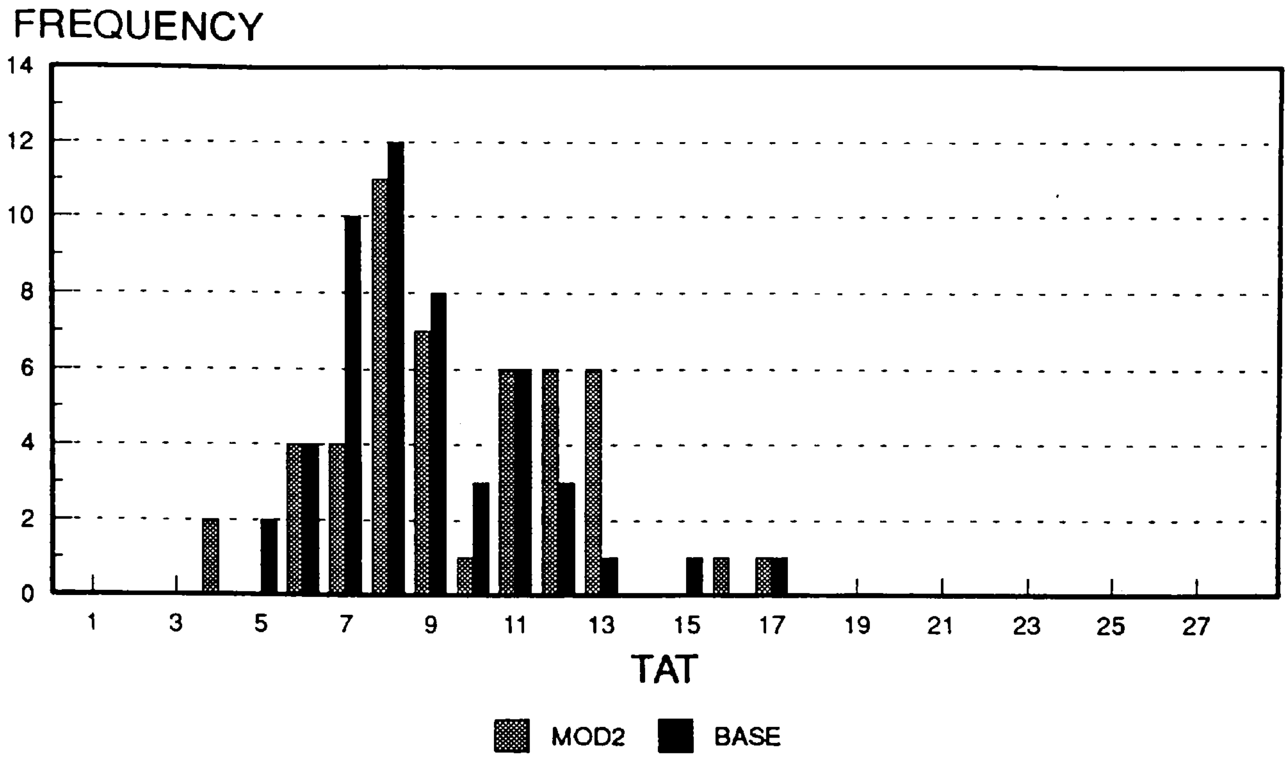
01 OLYMPUS STRIP ON NIGHTS



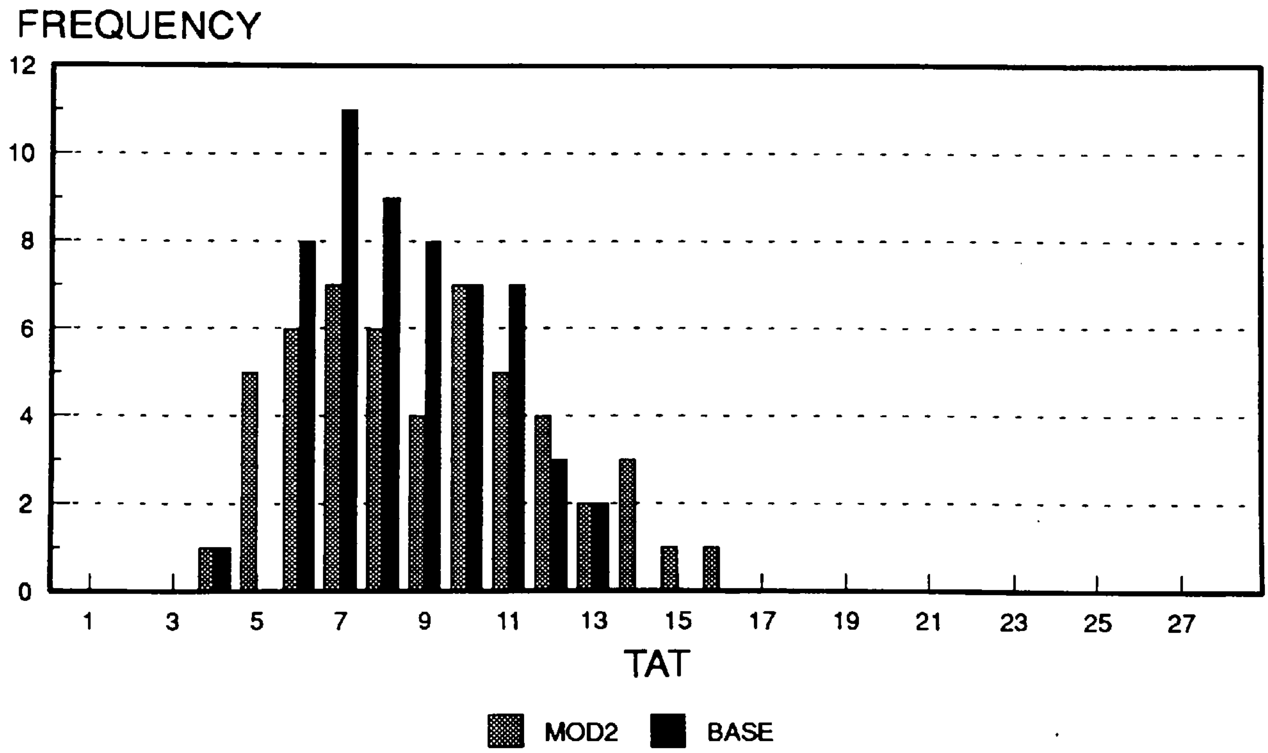
02 OLYMPUS STRIP ON NIGHTS



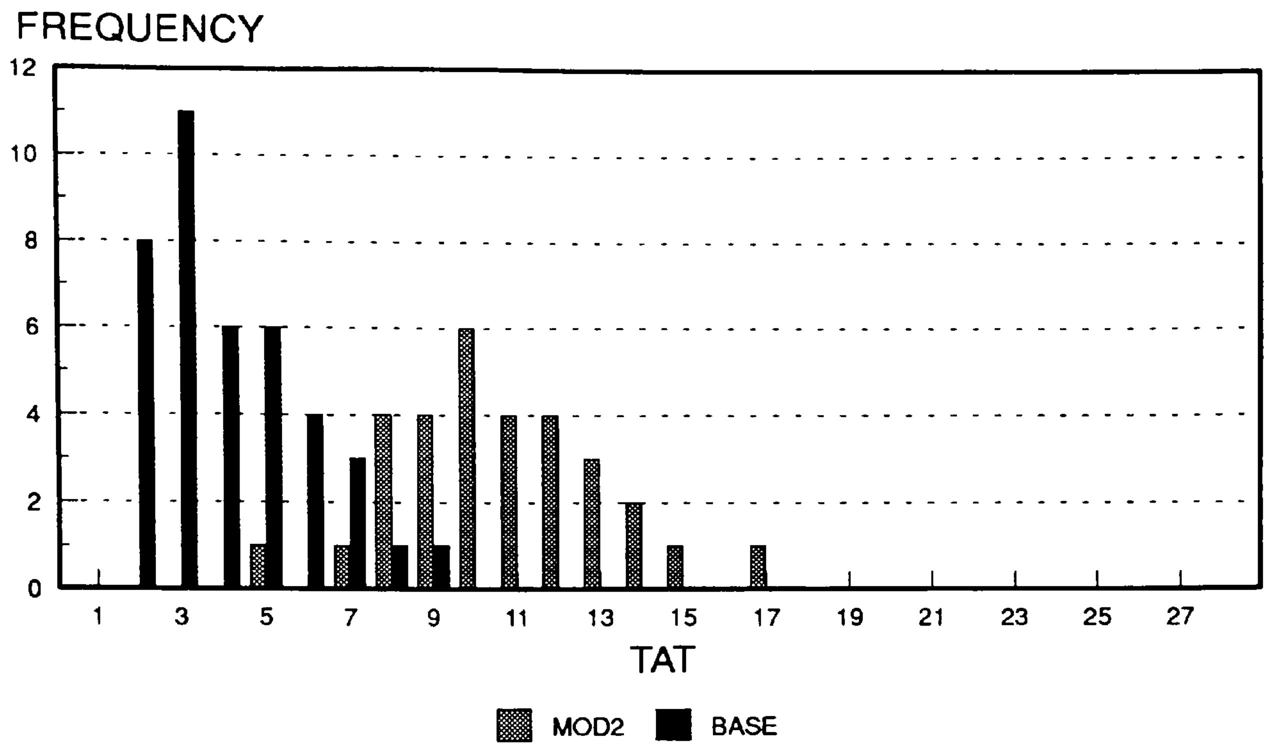
03 OLYMPUS STRIP ON NIGHTS



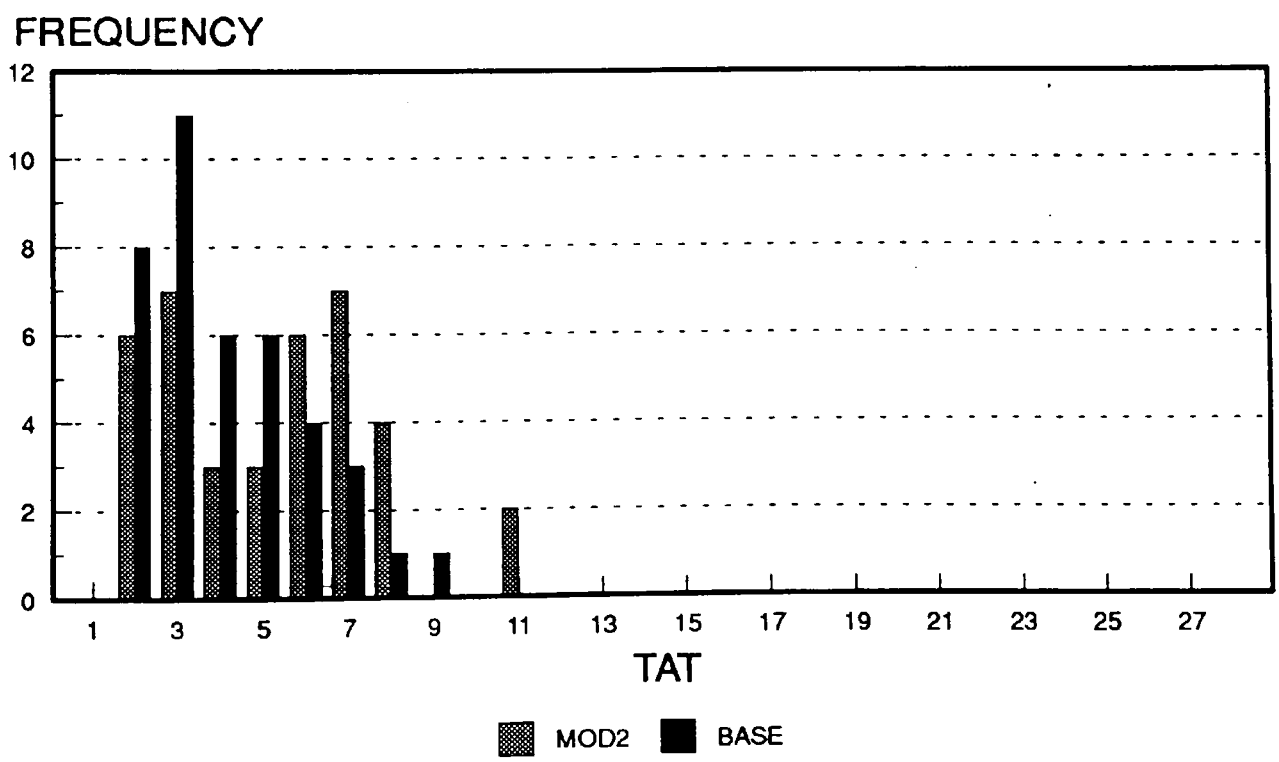
04 OLYMPUS STRIP ON NIGHTS

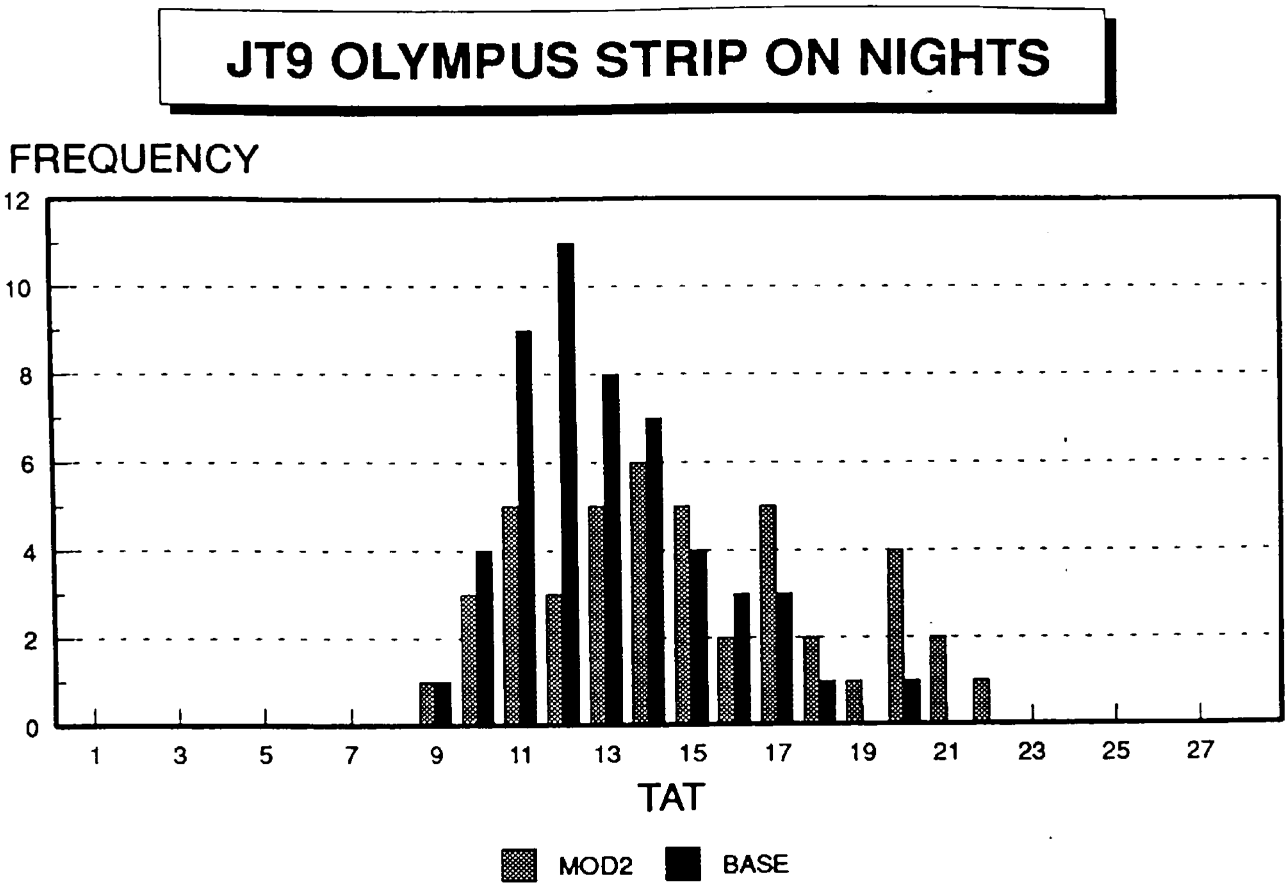


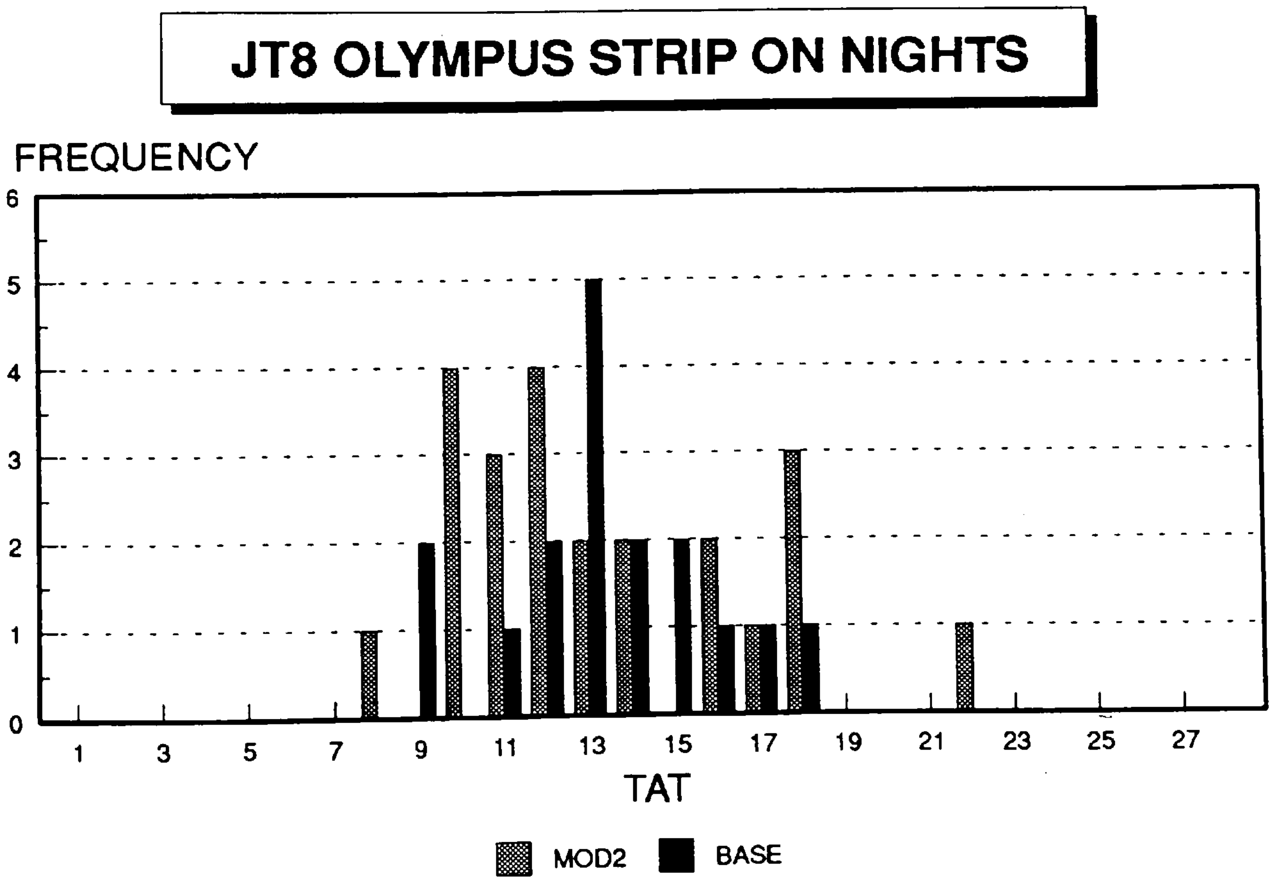
05 OLYMPUS STRIP ON NIGHTS

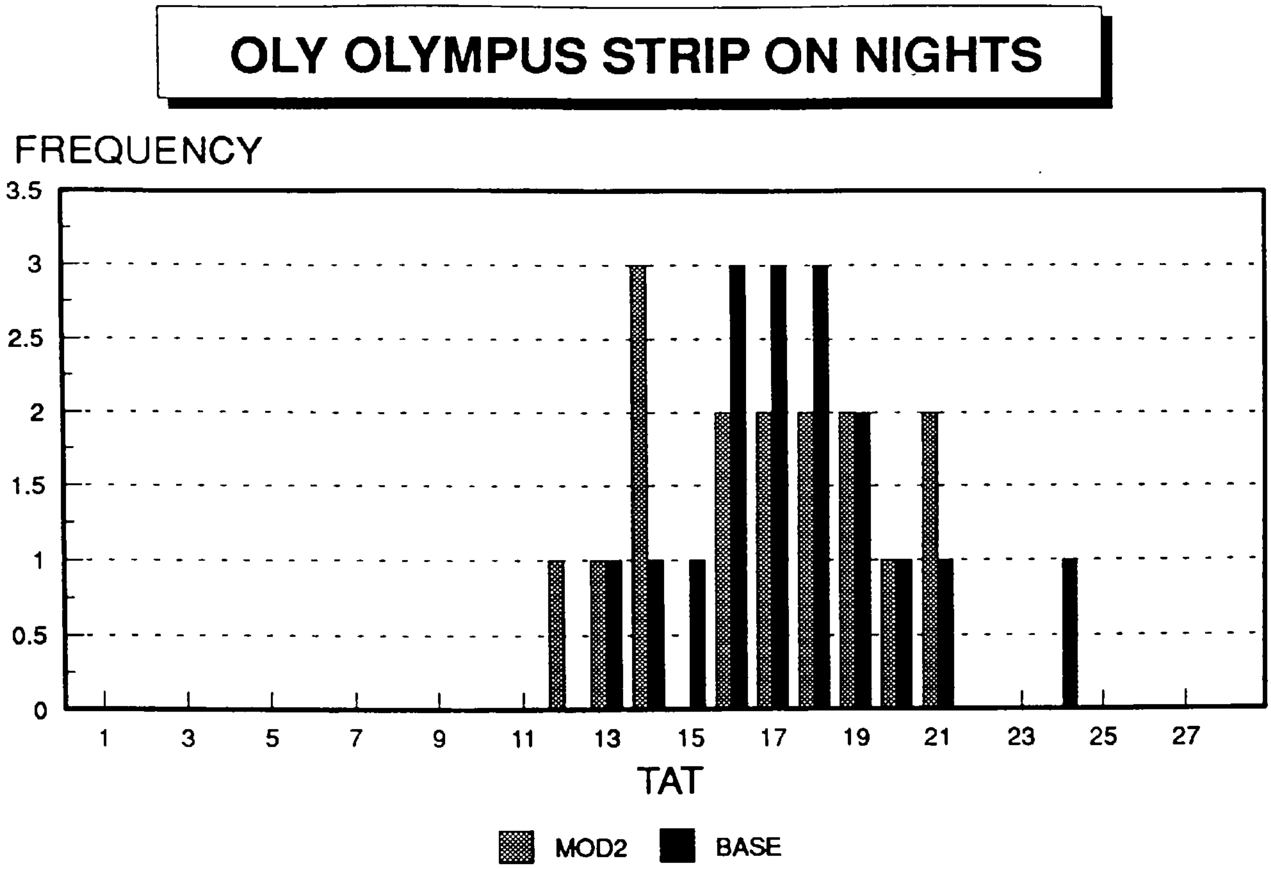


06 OLYMPUS STRIP ON NIGHTS




JT9 OLYMPUS STRIP ON NIGHTS
FREQUENCY
12
10
8
6
4
2
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
TAT
MOD2
BASE

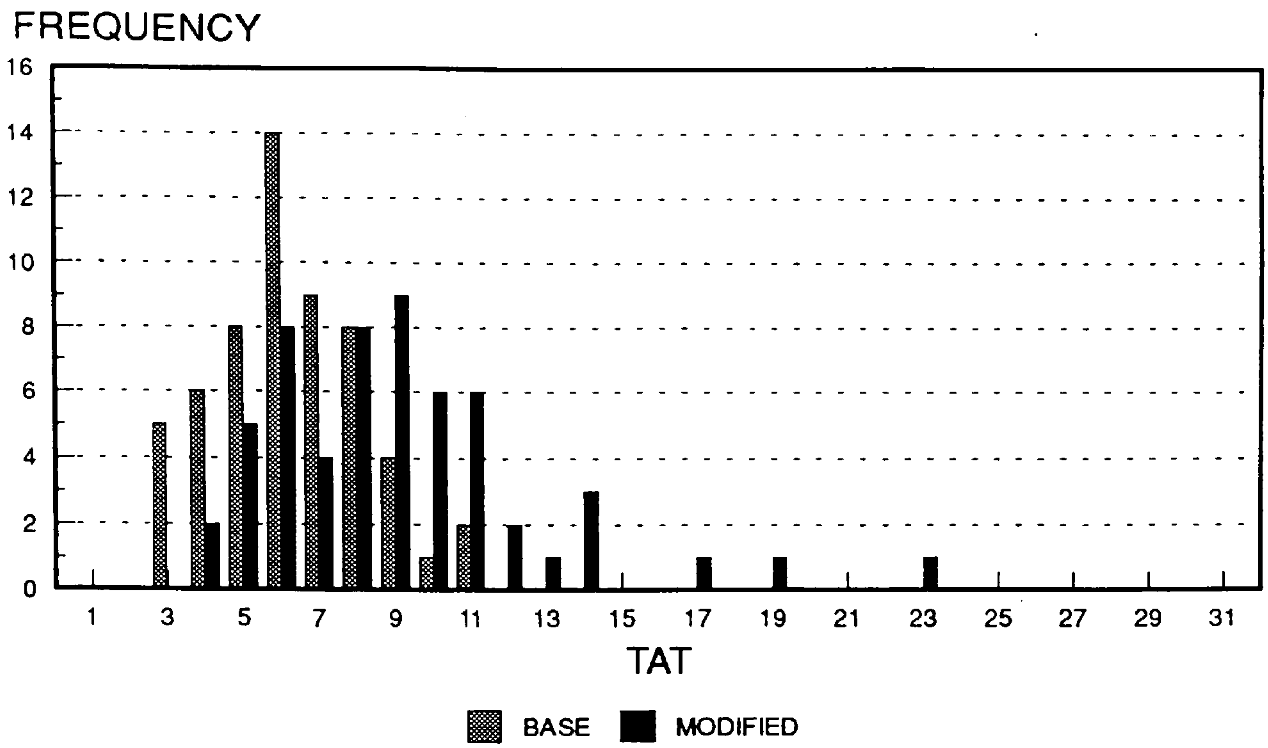

JT8 OLYMPUS STRIP ON NIGHTS
FREQUENCY
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
TAT
MOD2
BASE



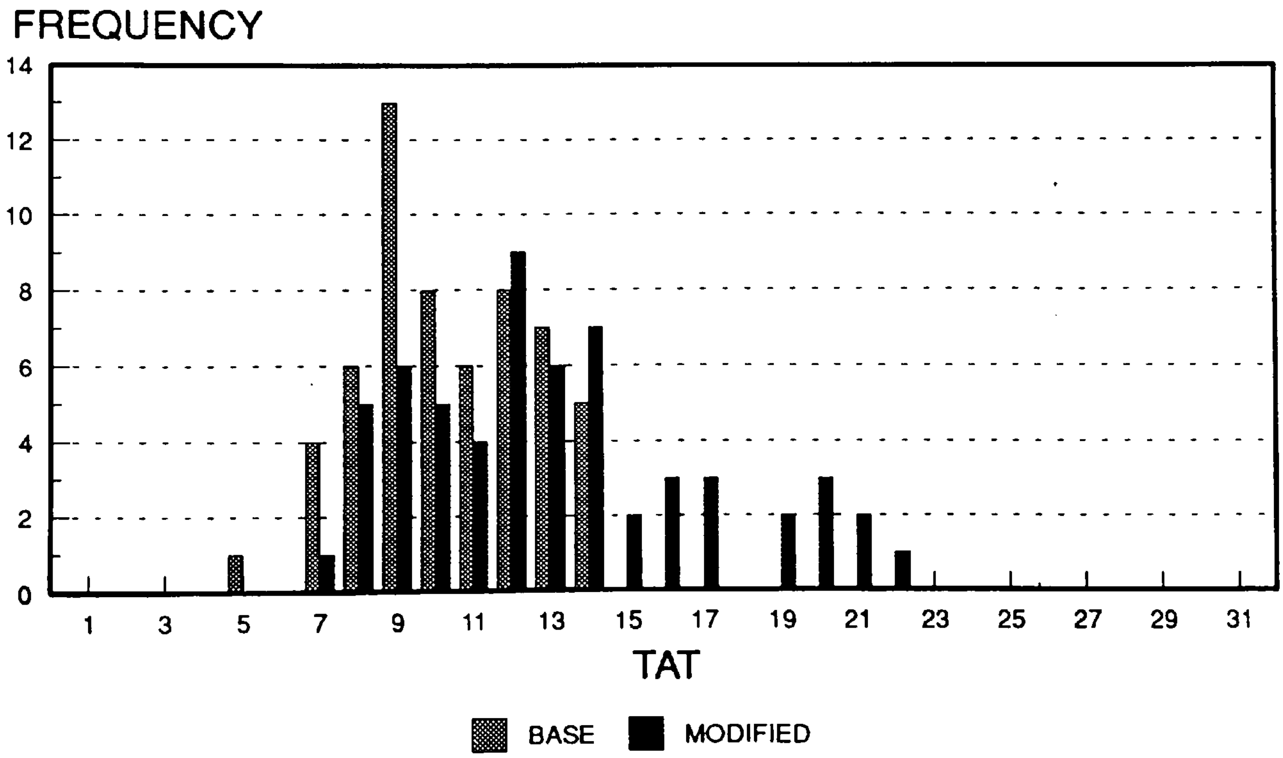
OLY OLYMPUS STRIP ON NIGHTS
FREQUENCY
3.5
3
2.5
2
1.5
1
0.5
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
TAT
MOD2
BASE

7.6) Increase of PM shift in the DVB

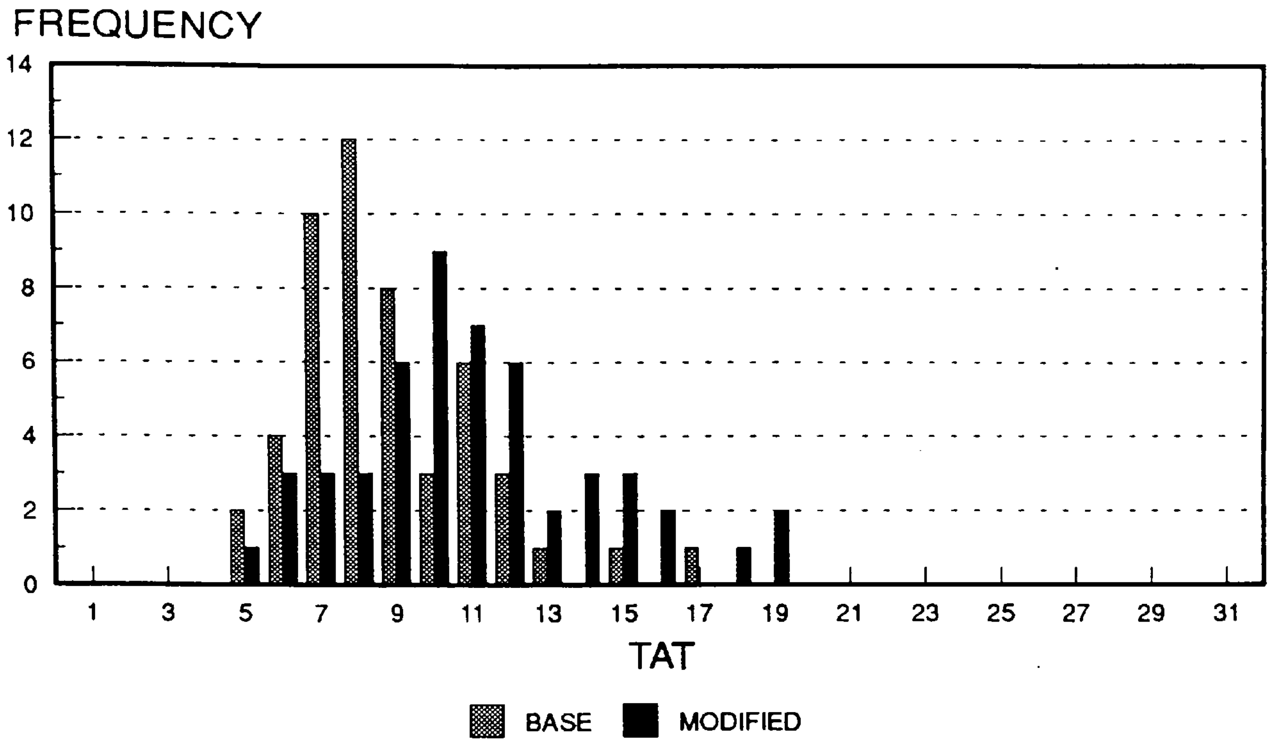
01 INCREASE OF PM SHIFT IN DVB



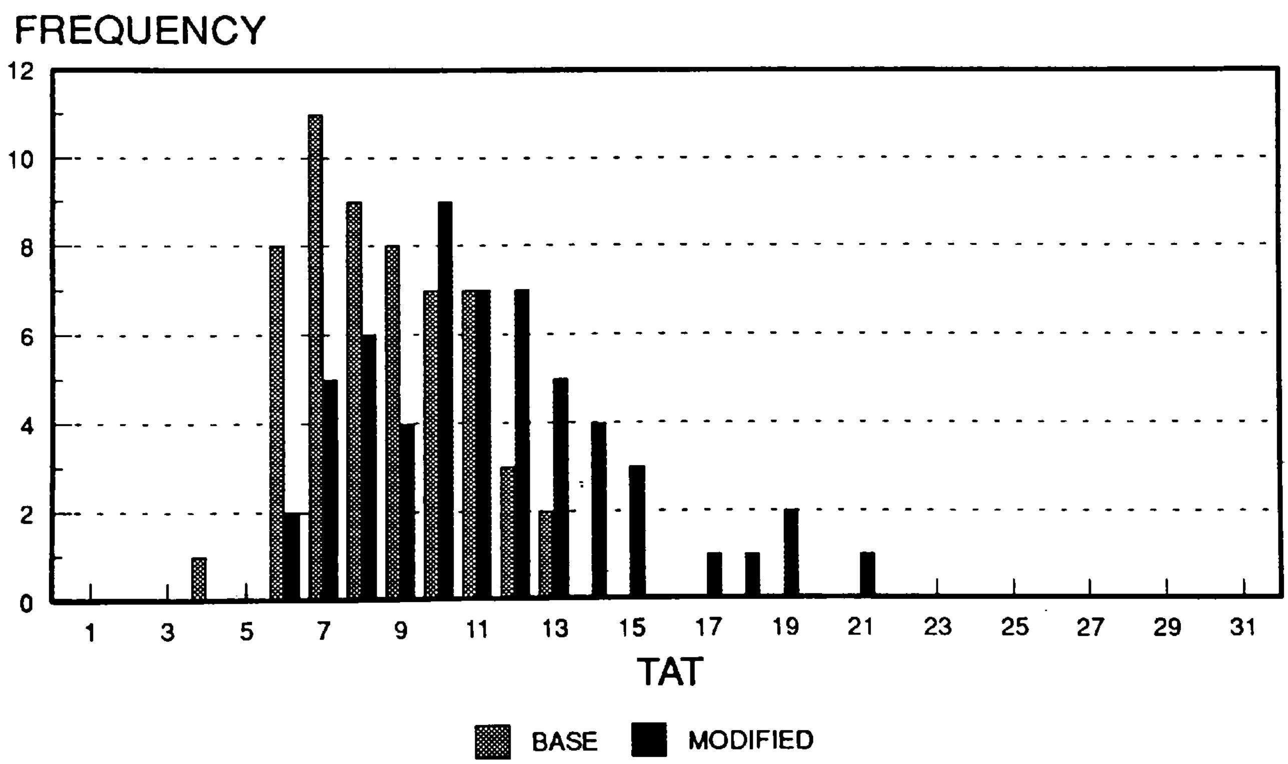
02 INCREASE OF PM SHIFT IN DVB



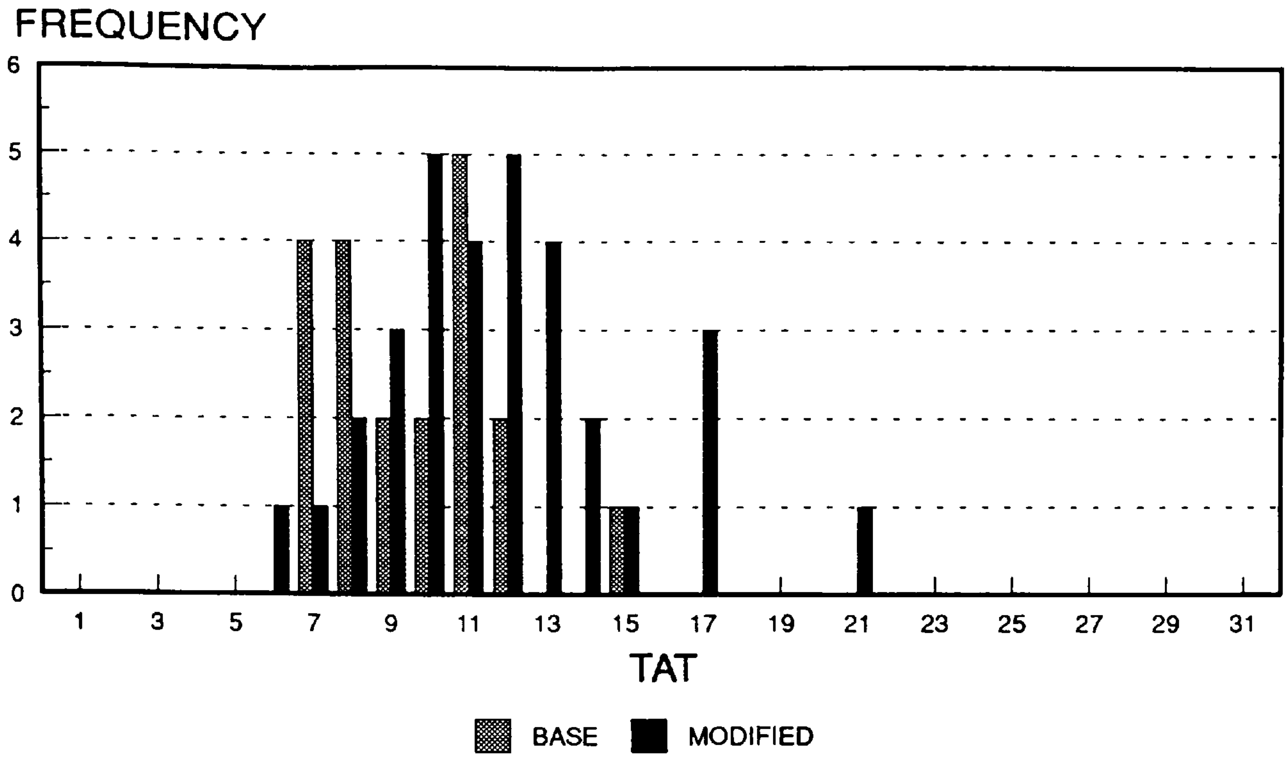
03 INCREASE OF PM SHIFT IN DVB



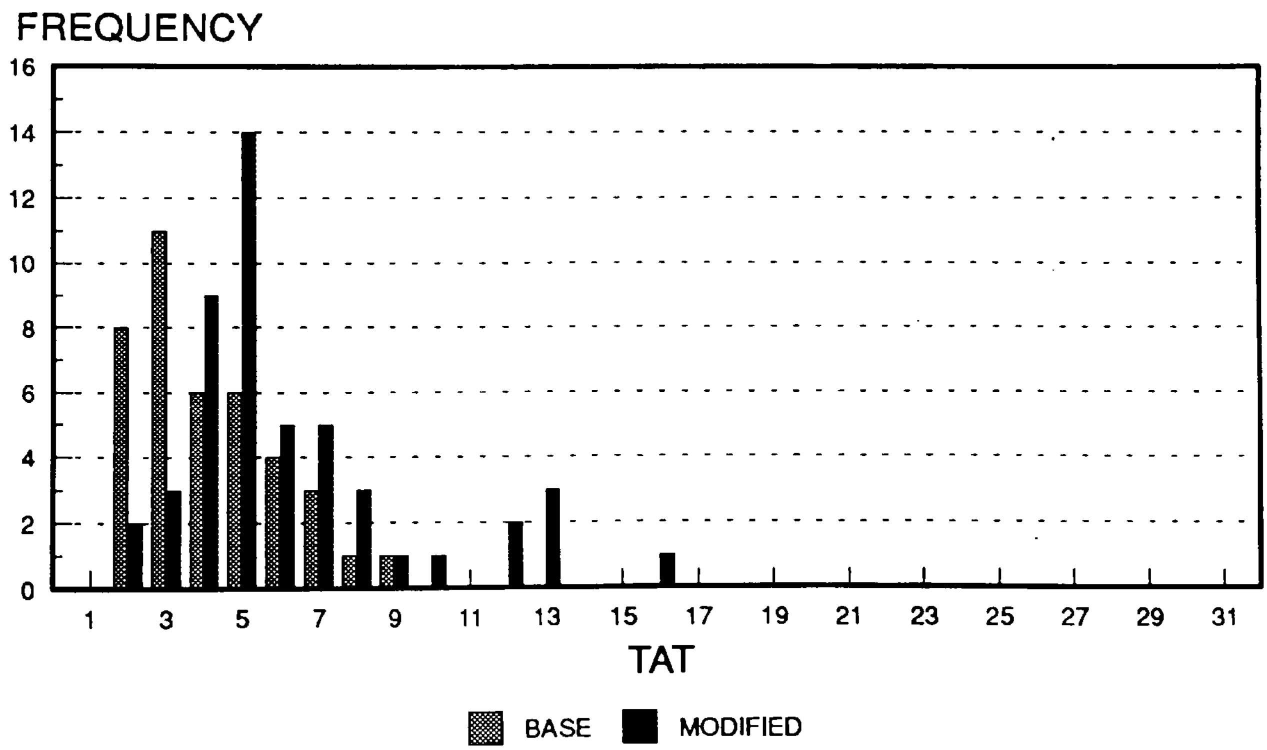
04 INCREASE OF PM SHIFT IN DVB



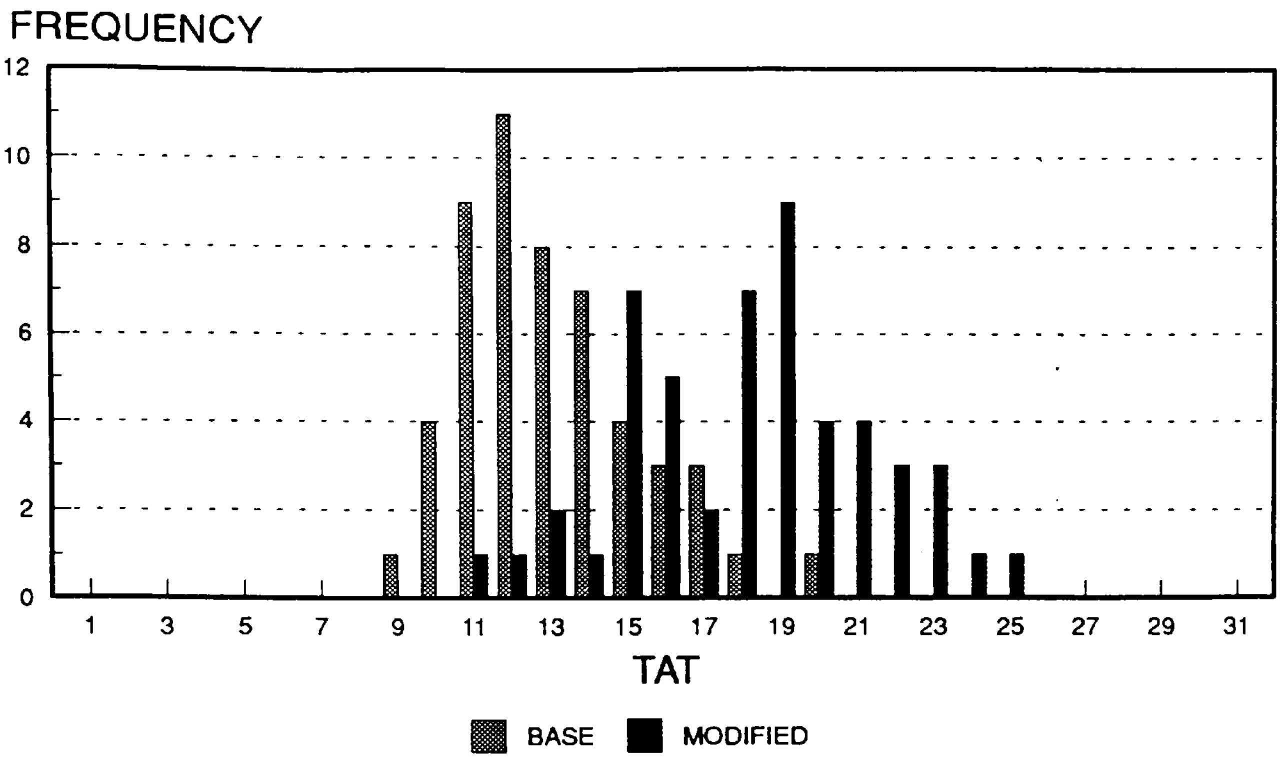
05 INCREASE OF PM SHIFT IN DVB



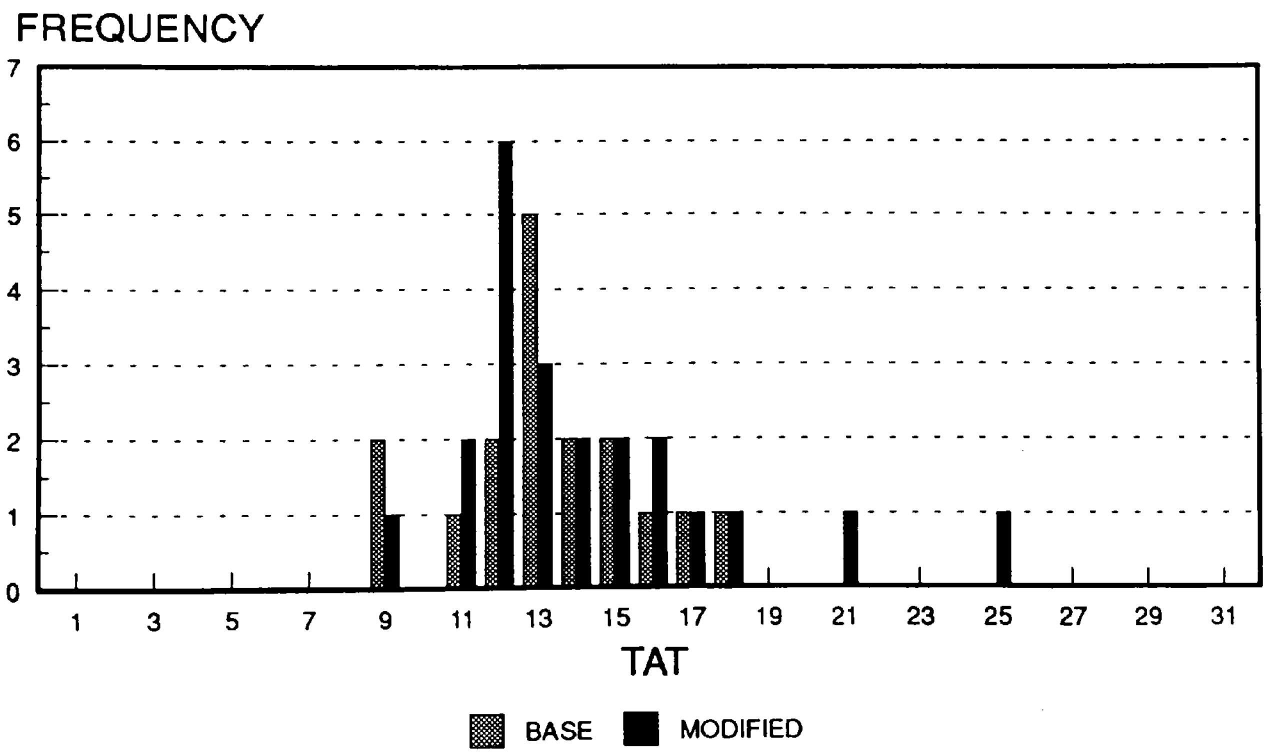
06 INCREASE OF PM SHIFT IN DVB

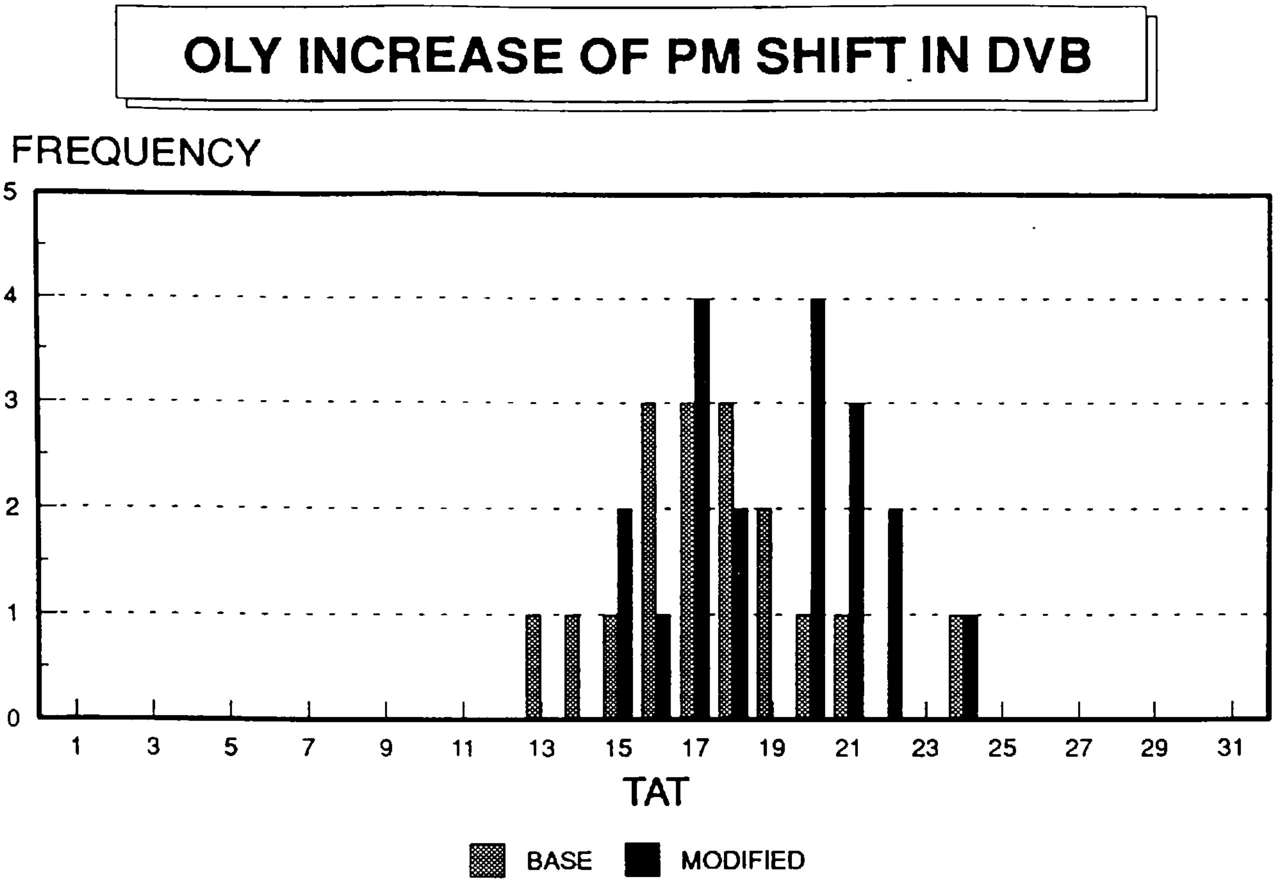


JT9 INCREASE OF PM SHIFT IN DVB



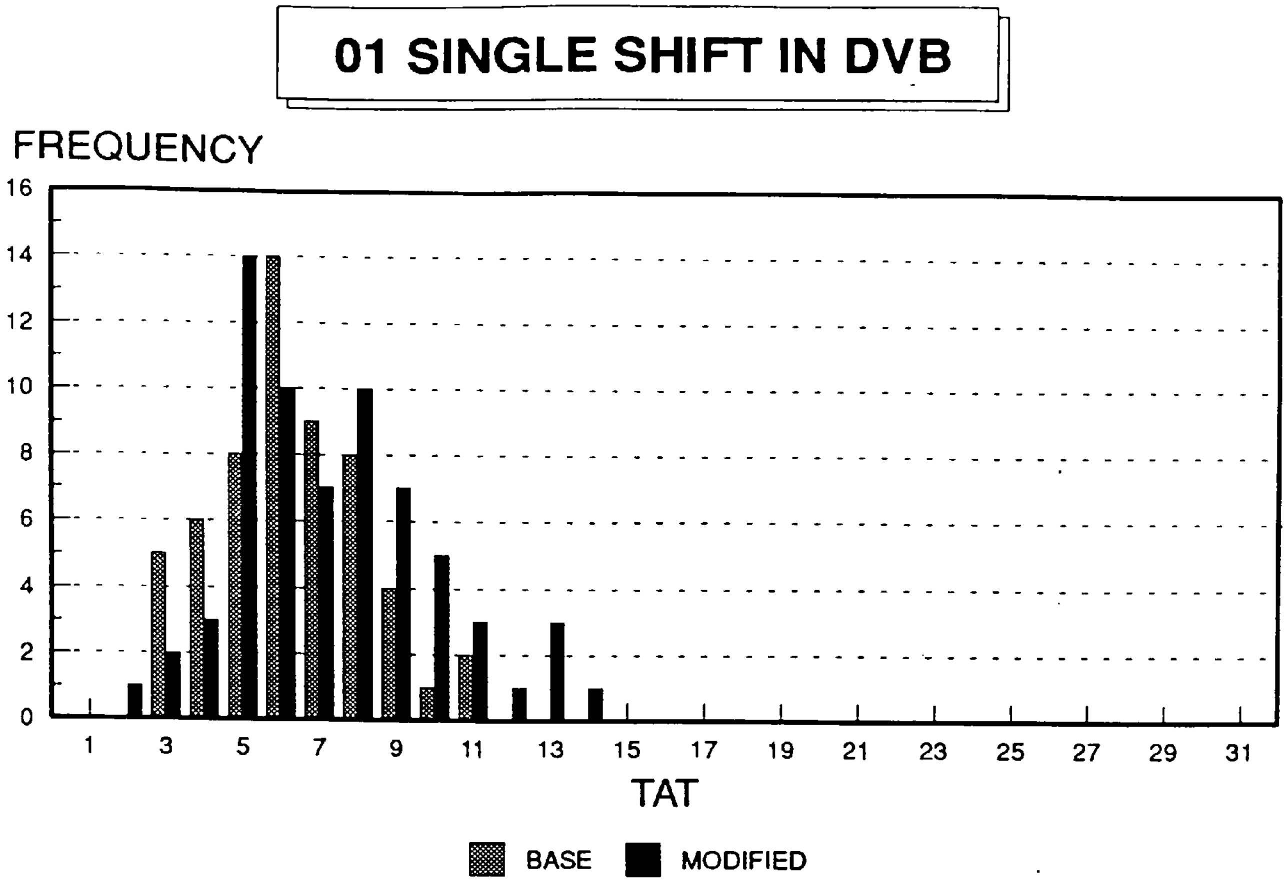
JT8 INCREASE OF PM SHIFT IN DVB

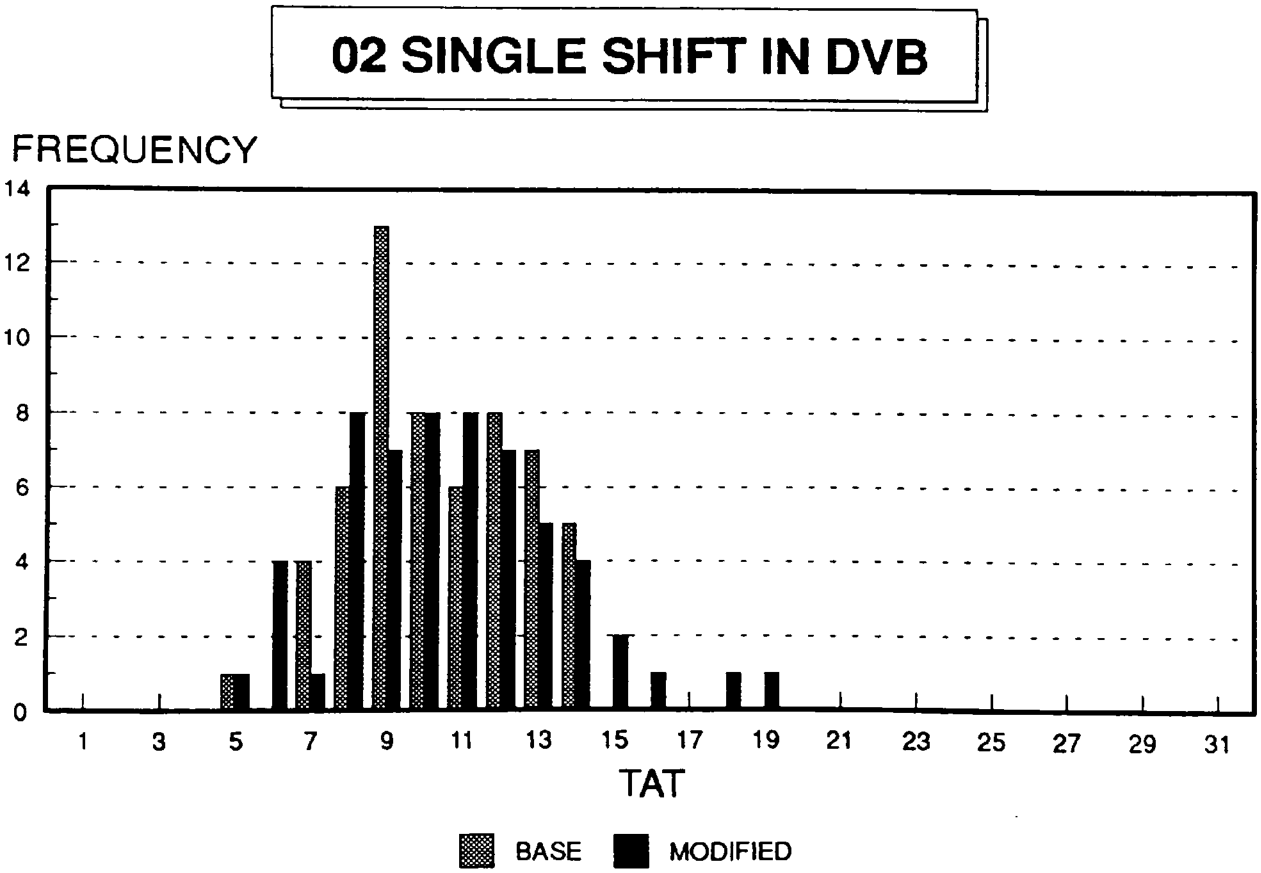


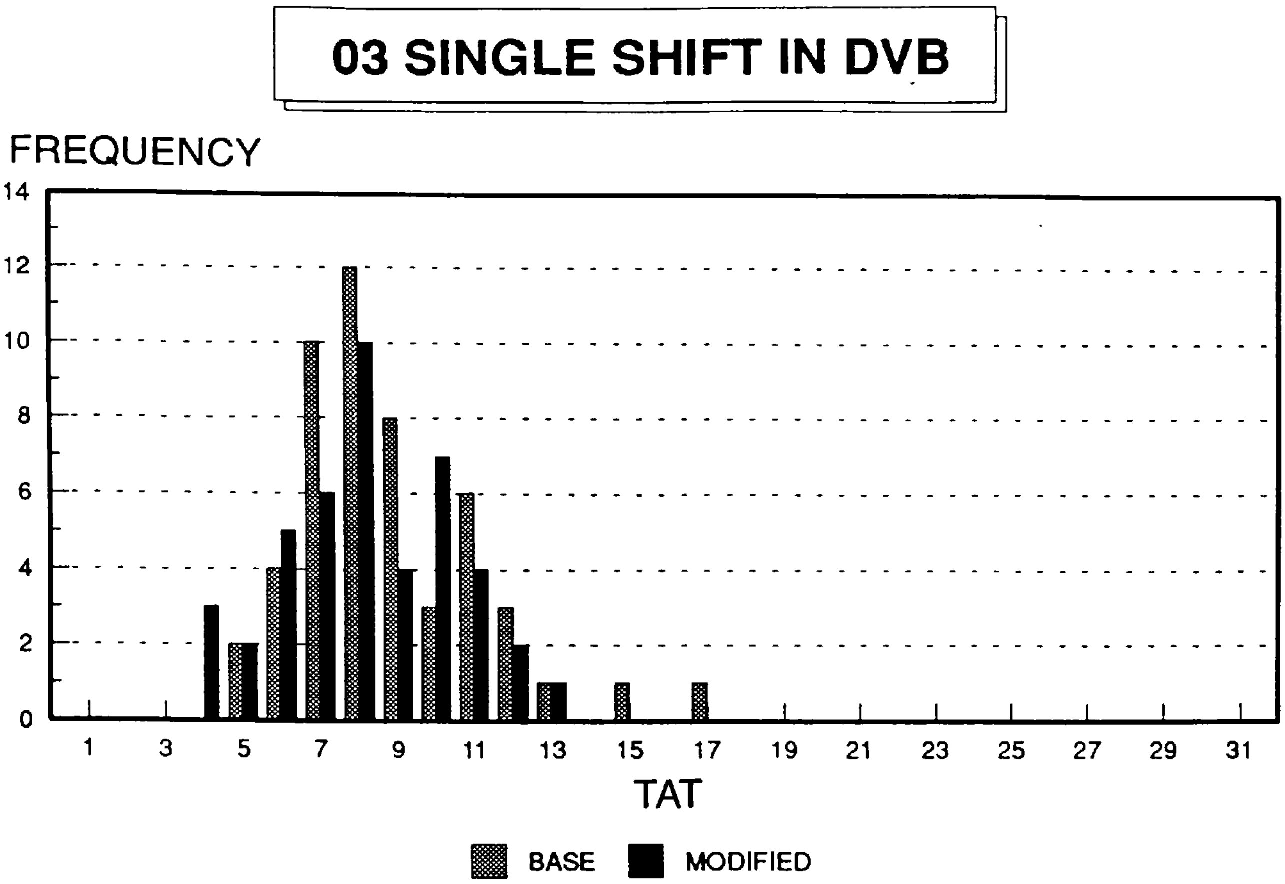


OLY INCREASE OF PM SHIFT IN DVB
FREQUENCY
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
TAT
BASE
MODIFIED

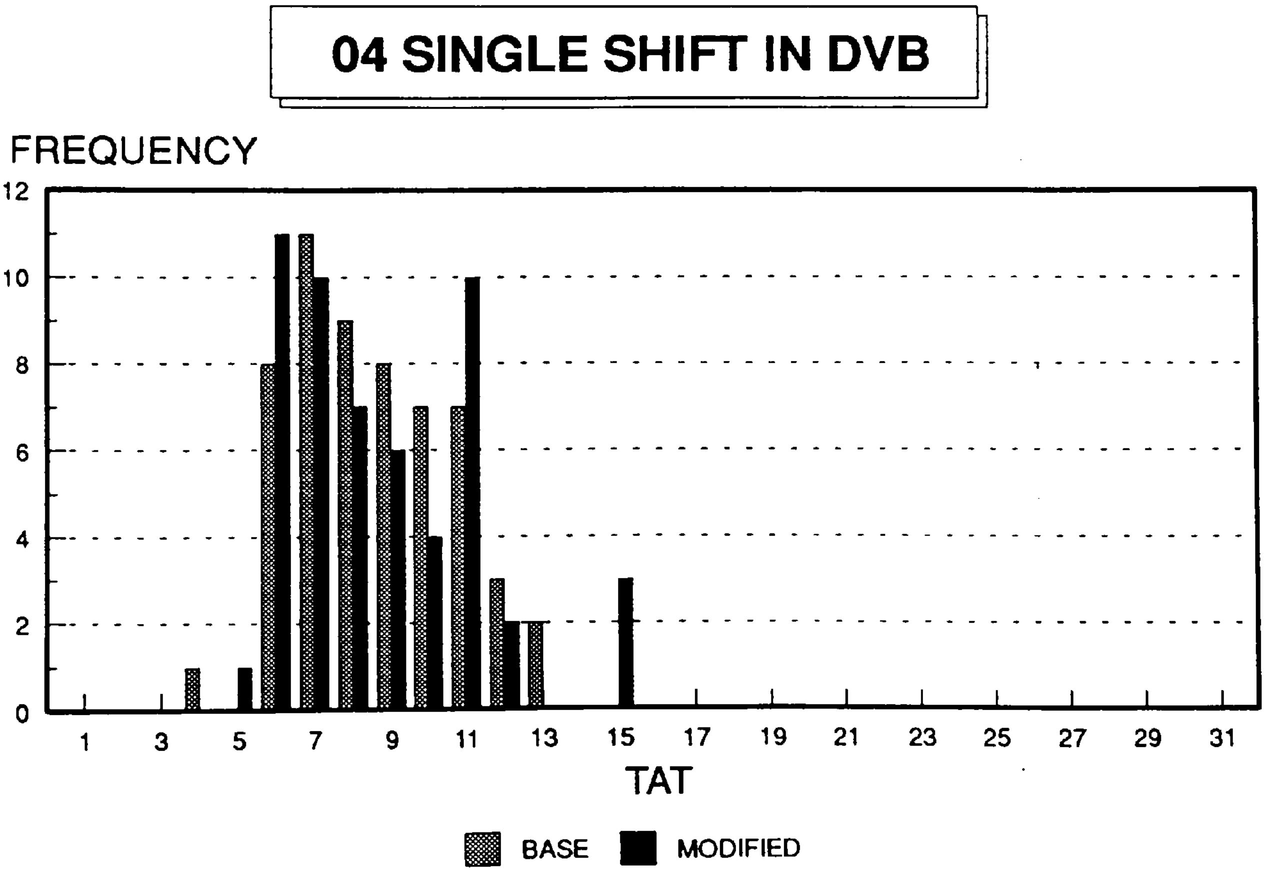
7.7) Implementation of single shift in DVB


01 SINGLE SHIFT IN DVB
FREQUENCY
16
14
12
10
8
6
4
2
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
TAT
BASE
MODIFIED


02 SINGLE SHIFT IN DVB
FREQUENCY
14
12
10
8
6
4
2
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
TAT
BASE
MODIFIED

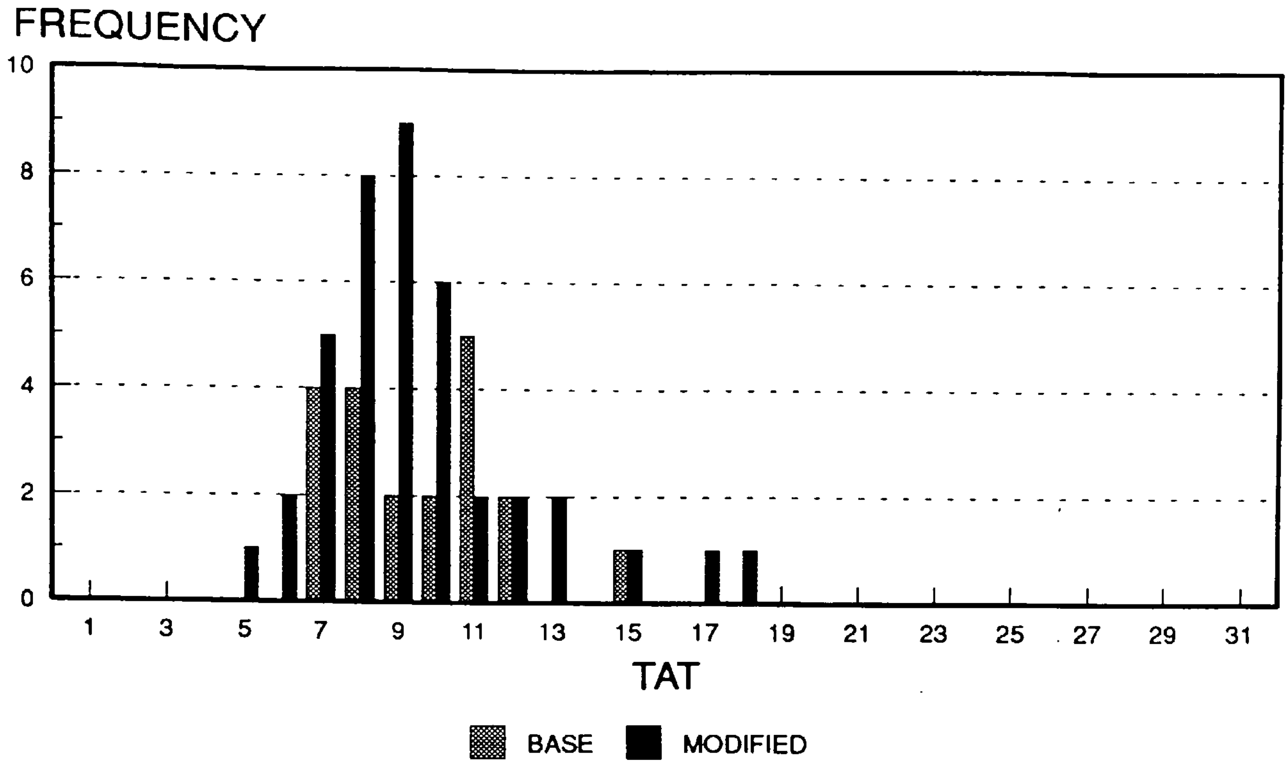


03 SINGLE SHIFT IN DVB
FREQUENCY
14
12
10
8
6
4
2
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
TAT
BASE
MODIFIED

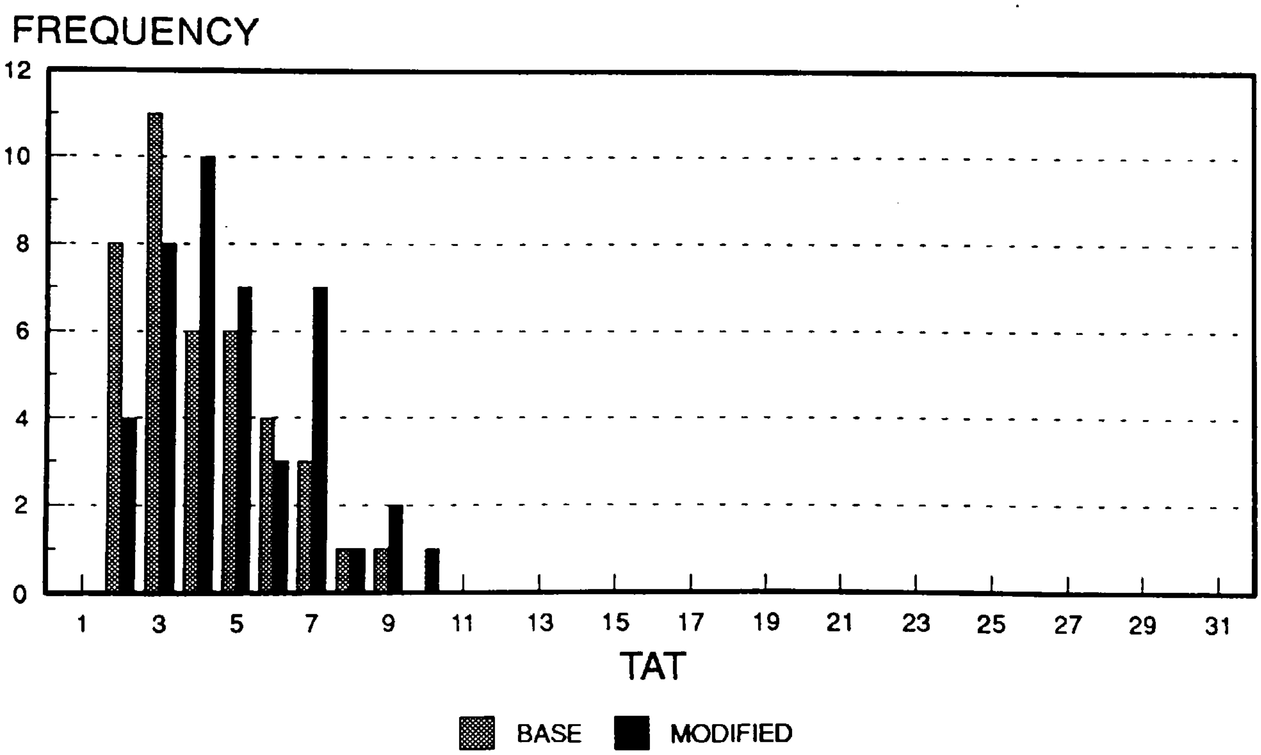


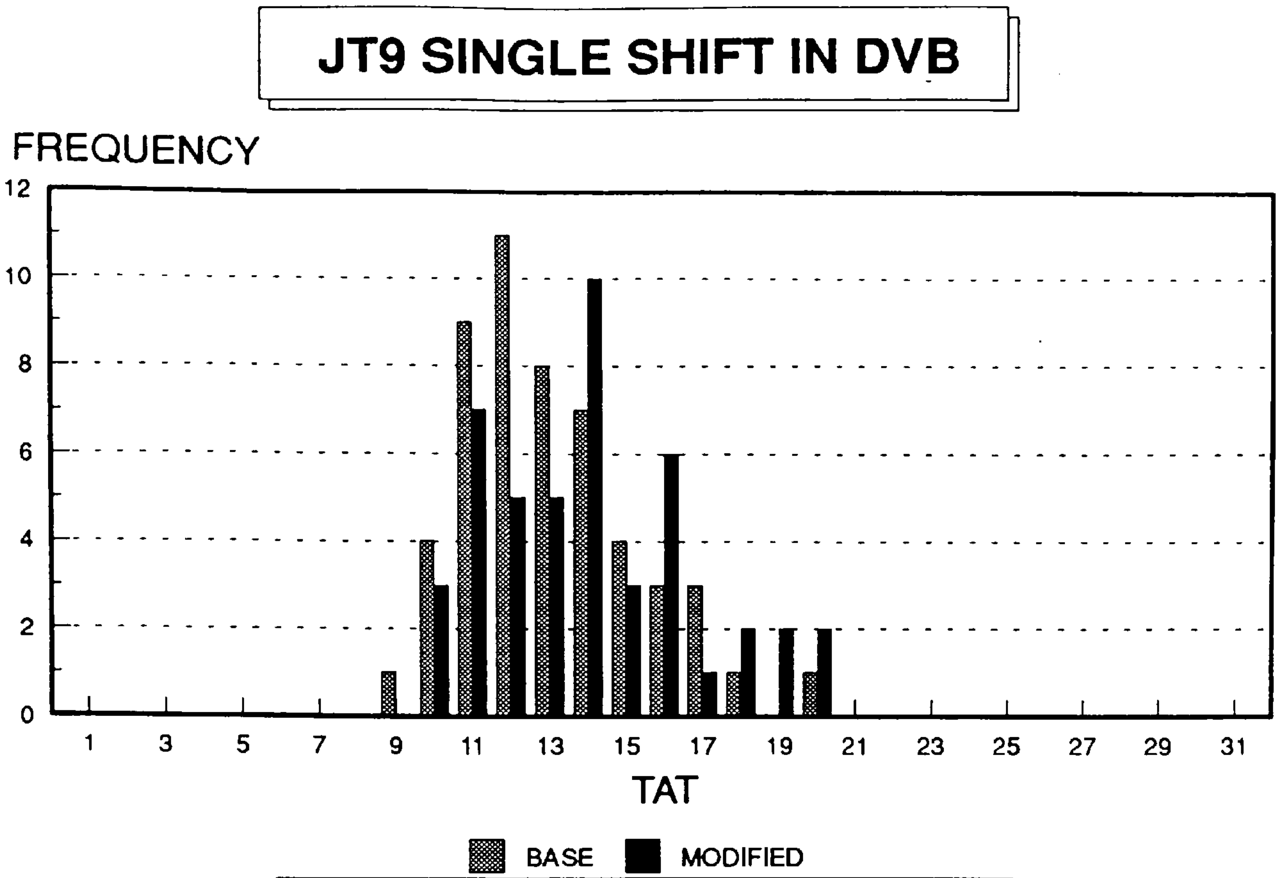
04 SINGLE SHIFT IN DVB
FREQUENCY
12
10
8
6
4
2
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
TAT
BASE
MODIFIED

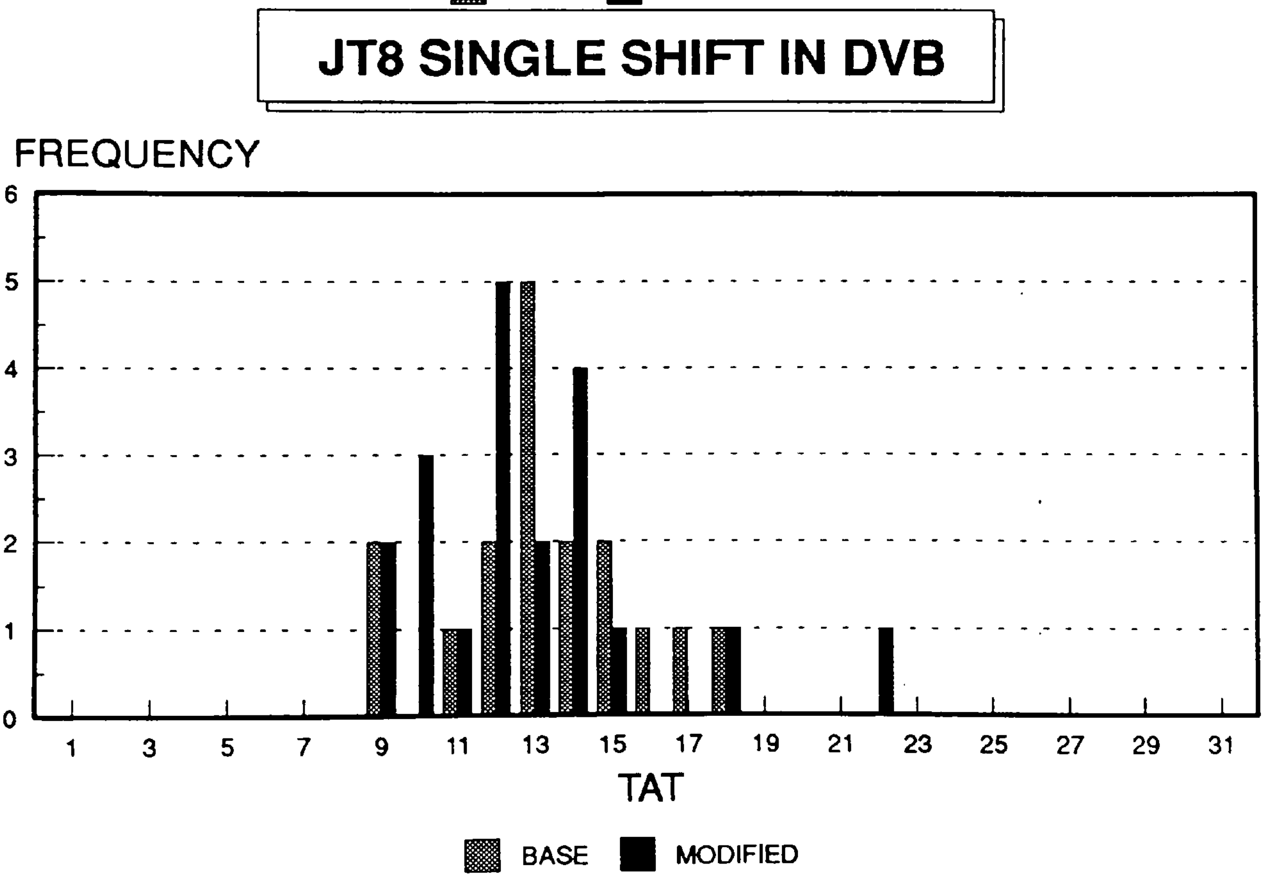
05 SINGLE SHIFT IN DVB

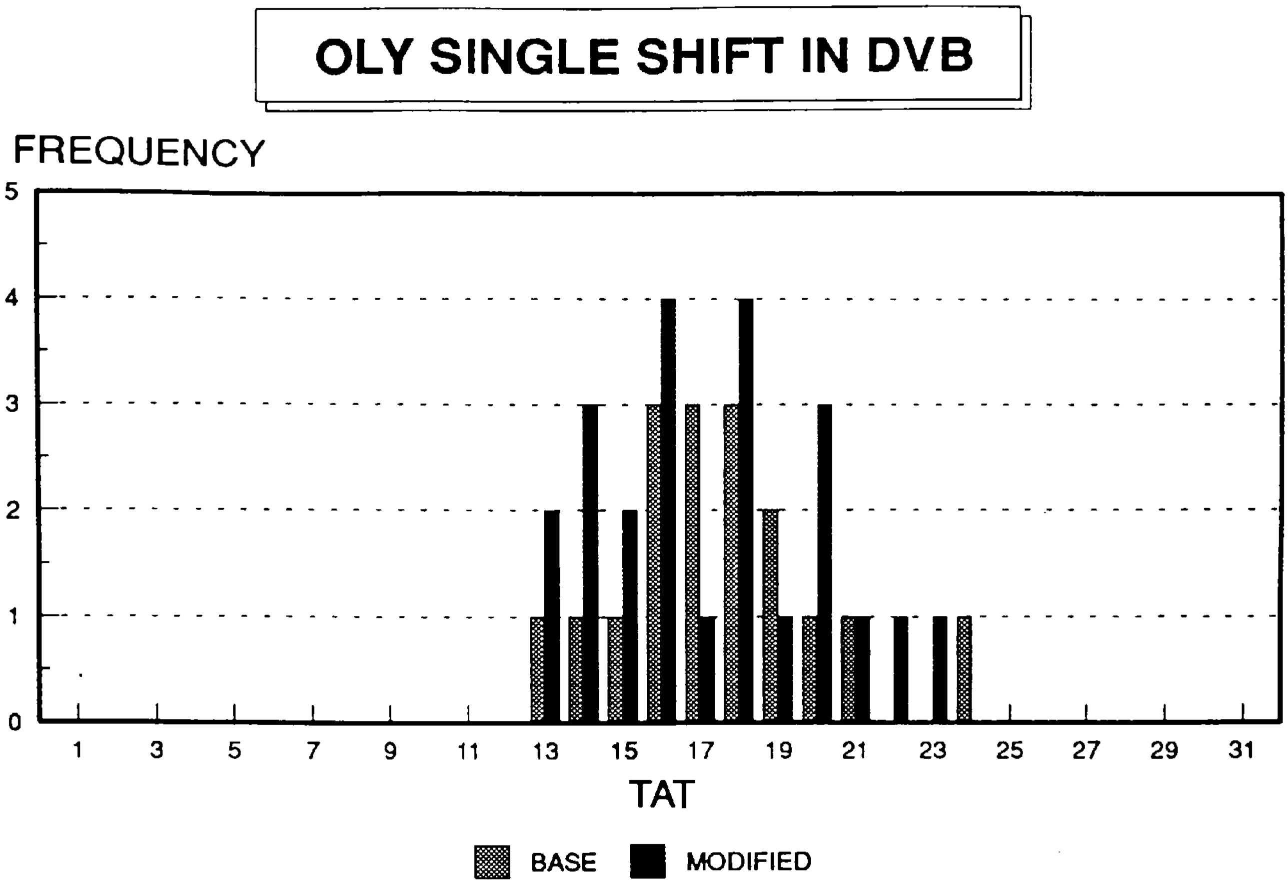


06 SINGLE SHIFT IN DVB




JT9 SINGLE SHIFT IN DVB
FREQUENCY
12
10
8
6
4
2
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
TAT
BASE
MODIFIED


JT8 SINGLE SHIFT IN DVB
FREQUENCY
6
5
4
3
2
1
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
TAT
BASE
MODIFIED


OLY SINGLE SHIFT IN DVB
FREQUENCY
0
1
2
3
4
5
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
TAT
BASE
MODIFIED

Appendix 8

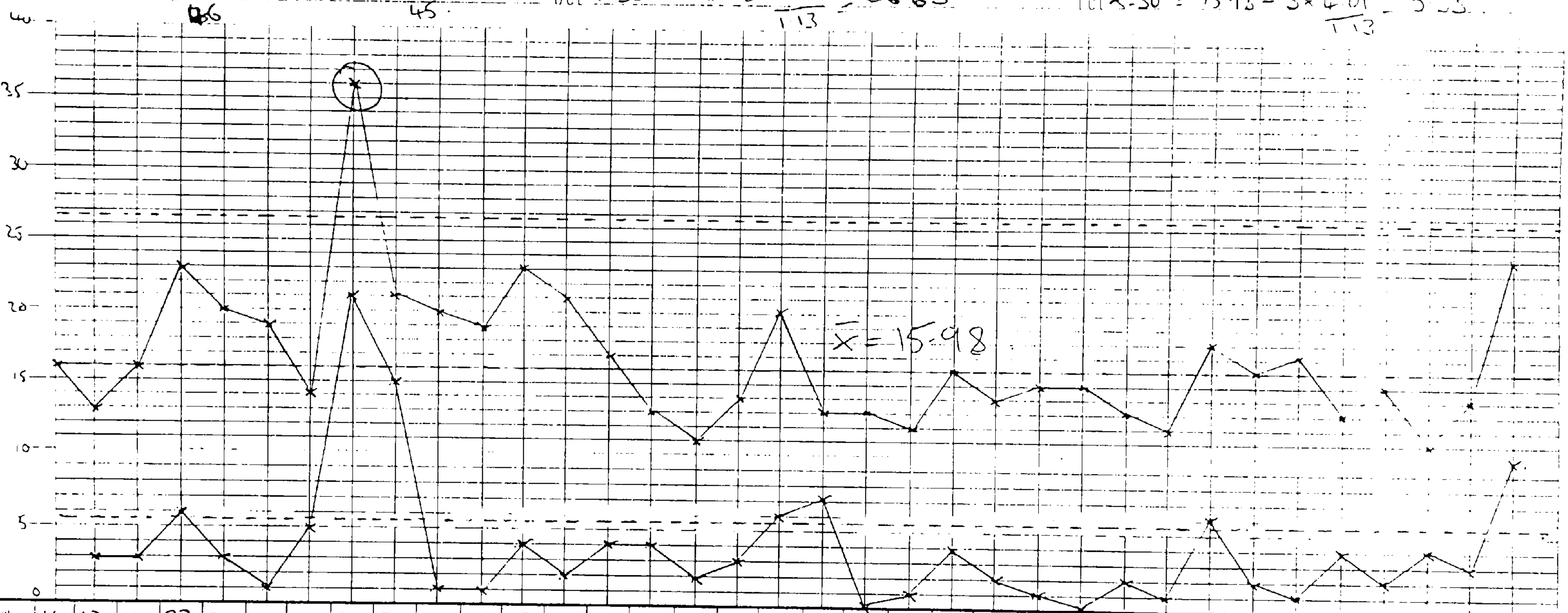
Shopfloor Generated Statistical Process Control (SPC) Charts

Control Chart
Attribute Data

JT9 (1) TAT Time SPC Chart

Part Number: JT9 (1)

Avg $\bar{x} = \frac{735}{46}$ 15.98 $\bar{R} = \frac{184}{45} = 4.01$ UCL $\bar{x}+3\sigma = 15.98 + 3 \times \frac{4.01}{1.13} = 26.63$ LCL $\bar{x}-3\sigma = 15.98 - 3 \times \frac{4.01}{1.13} = 5.33$



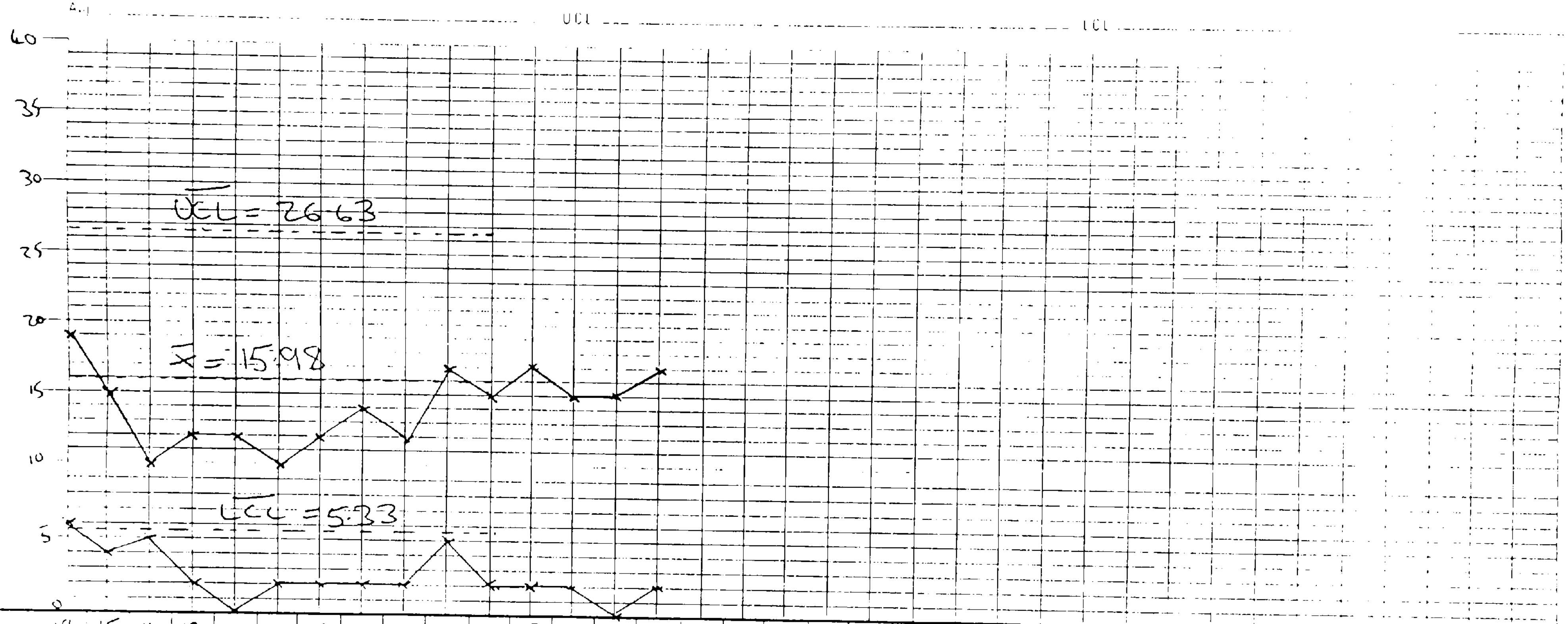
16	13	16	23	20	19	14	36	21	20	19	23	21	17	13	11	14	20	13	13	12	16	14	15	15	13	12	18	16	17	13	15	11	14	24
	3	3	6	3	1	5	21	15	1	1	4	2	4	4	2	3	6	7	0	1	4	2	1	0	2	1	6	2	1	4	2	4	3	10

Date	Time	Comments	Date	Time	Comments

Control Chart
Attribute Data

JT9 (2) TAT Time SPC Chart

JT9 (7)



19	15	10	12	12	10	12	14	12	17	15	17	15	15	17
				5					10					
6	4	5	2	0	2	2	2	2	5	2	2	2	0	2

Comments	Date	Time

Control Chart
Attribute Data

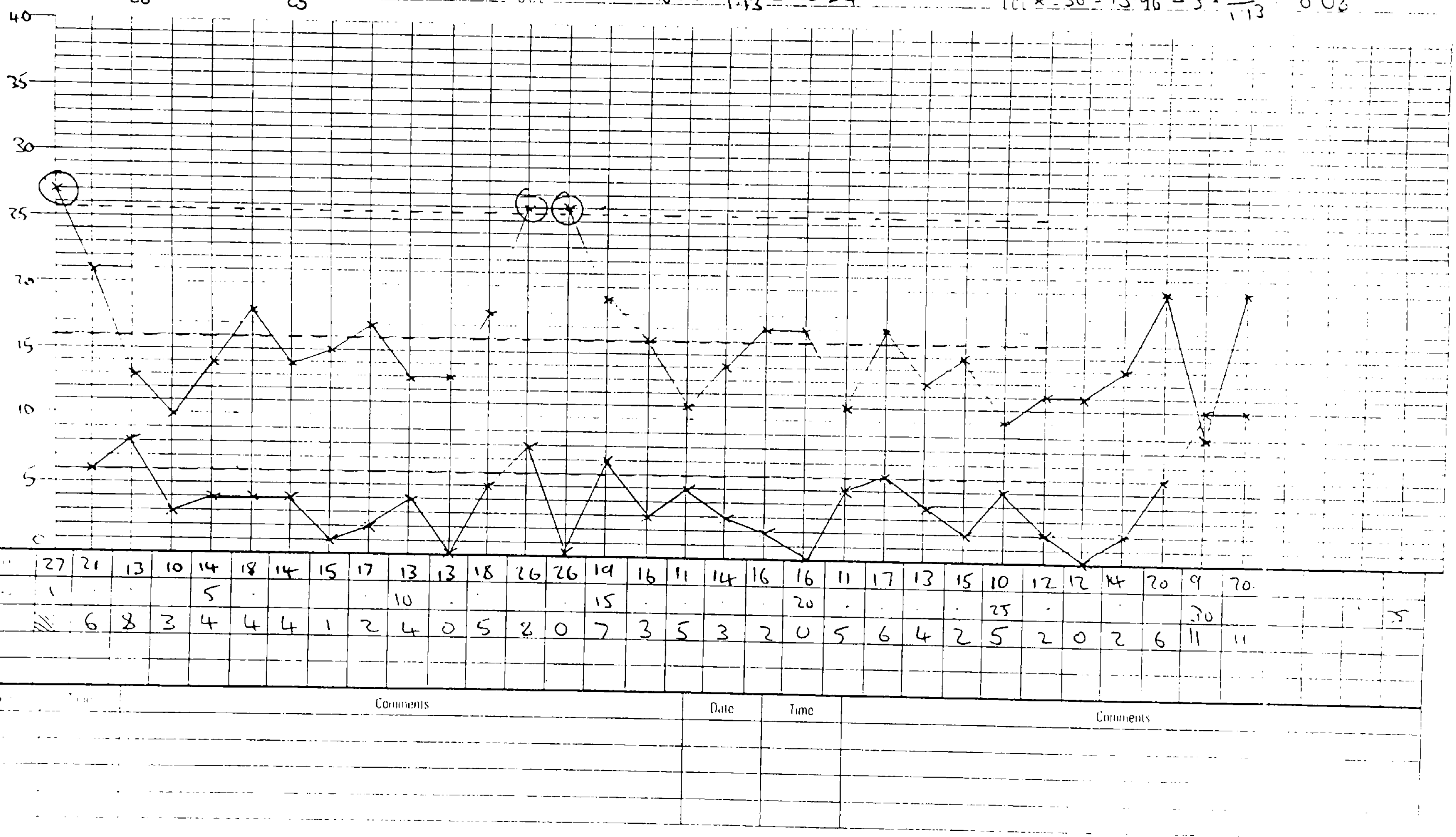
JT8 (1) TAT Time SPC Chart

Part Number: JT8 - (1).

Avg $\bar{x} = \frac{415}{26} = 15.96$ $\bar{R} = \frac{93}{25} = 3.72$

UCL $\bar{x} + 3\sigma = 15.96 + 3 \times \frac{3.72}{1.13} = 25.84$

LCL $\bar{x} - 3\sigma = 15.96 - 3 \times \frac{3.72}{1.13}$ 6.08



Control Chart
Attribute Data

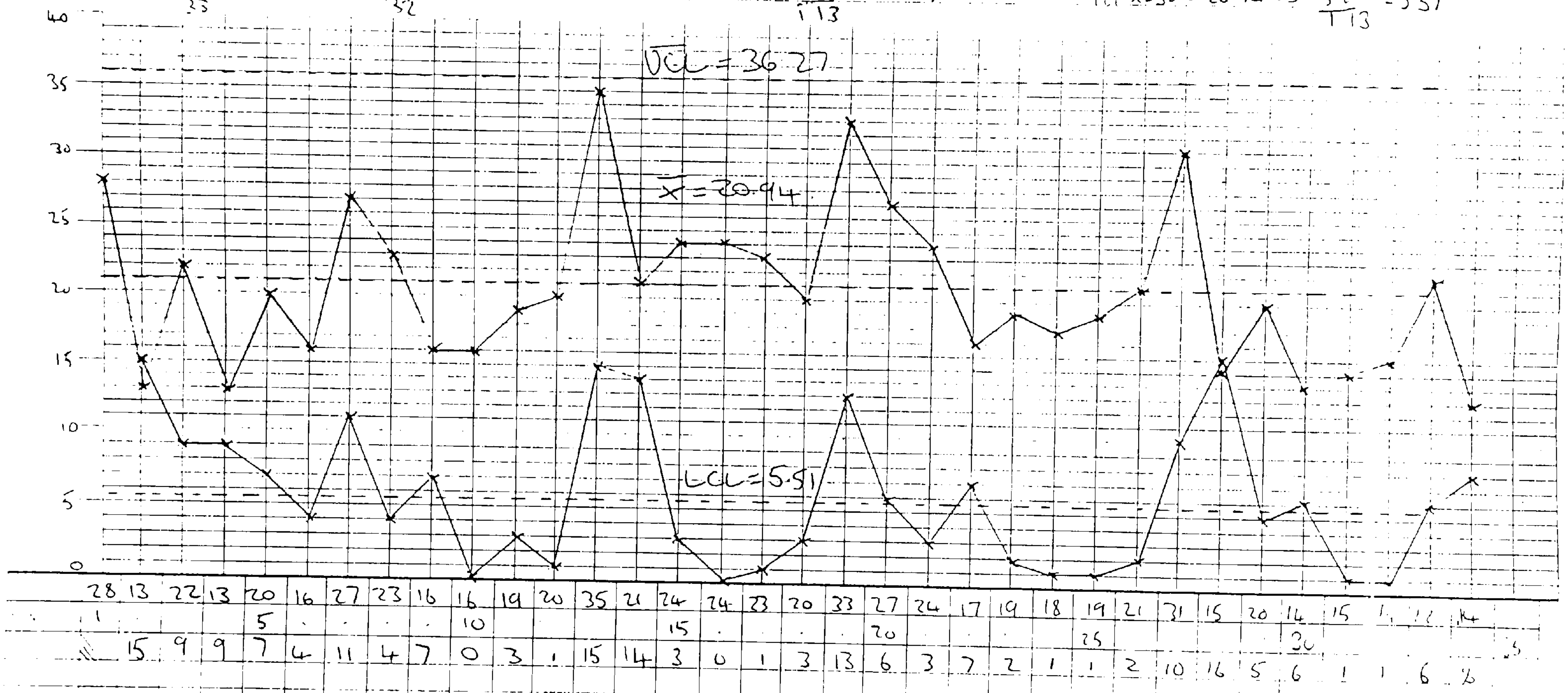
Olympus (1) TAT Time SPC Chart

Olympus (1)

$\bar{x} = \frac{691}{33} = 20.94$ $\bar{R} = \frac{176}{32} = 5.81$

UCL $\bar{x} + 3\sigma = 20.94 + 3 \times \frac{5.81}{1.13} = 36.37$

LCL $\bar{x} - 3\sigma = 20.94 - 3 \times \frac{5.81}{1.13} = 5.51$



Comments | Date | Time | Comments

Control Chart
Attribute Data

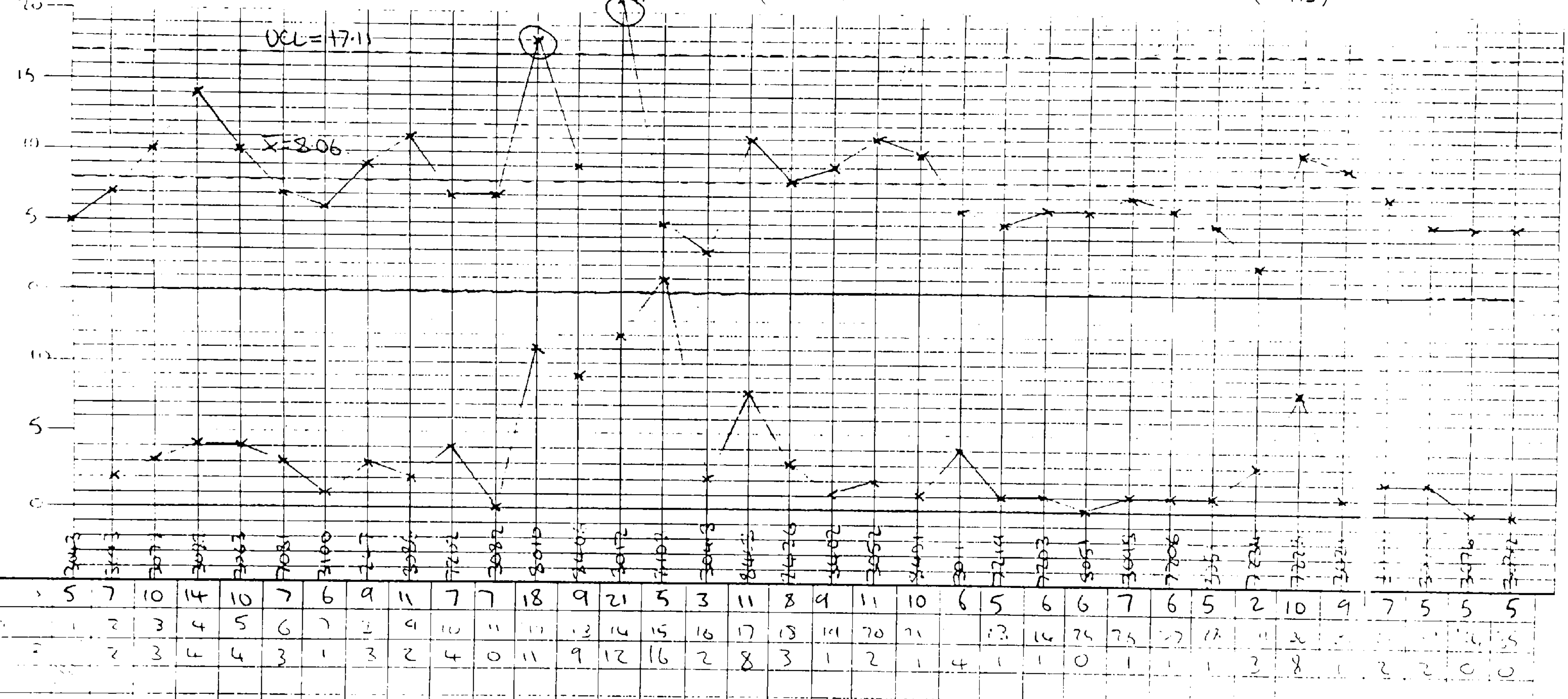
RB211 01 Module (1) TAT Time SPC Chart

01 – 1)

Avr $\bar{x} = \frac{282}{35} = 8.06$, $\bar{R} = \frac{116}{34} = 3.41$

UCL $= \bar{x} + 3\sigma = 8.06 + 3 \times \frac{3.41}{1.13}) = 17.11$

LCL $\bar{x} - 3\sigma = 8.06 - (3 \times \frac{3.41}{1.13}) = 0$



Comments	Date	Time	Comments

Control Chart
Attribute Data

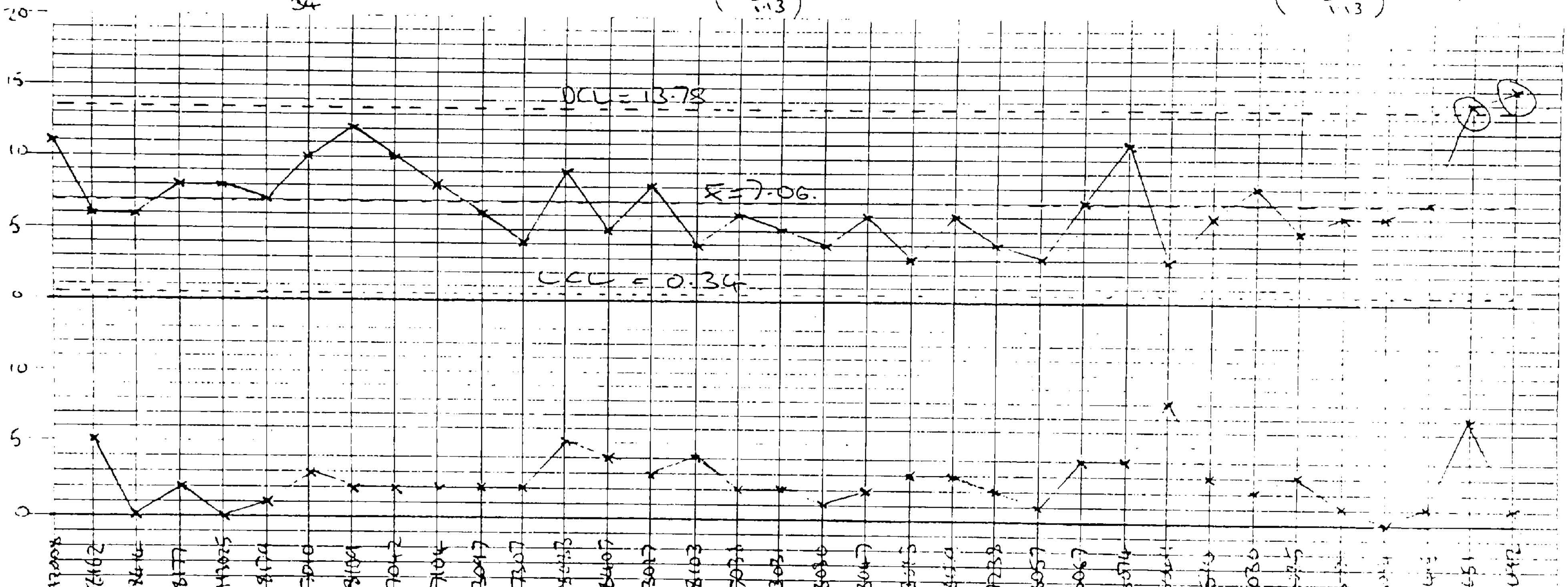
RB211 01 Module (2) TAT Time SPC Chart

01 - (2)

$\bar{\bar{x}} = \frac{247}{35} = 7.06$, $\bar{R} = \frac{86}{34} = 2.53$

UCL $\bar{x} + 3\sigma = 7.06 + 3 \times \frac{2.53}{1.13} = 13.78$

LCL $\bar{x} - 3\sigma = 7.06 - \left(3 \times \frac{2.53}{1.13}\right) = 0.34$

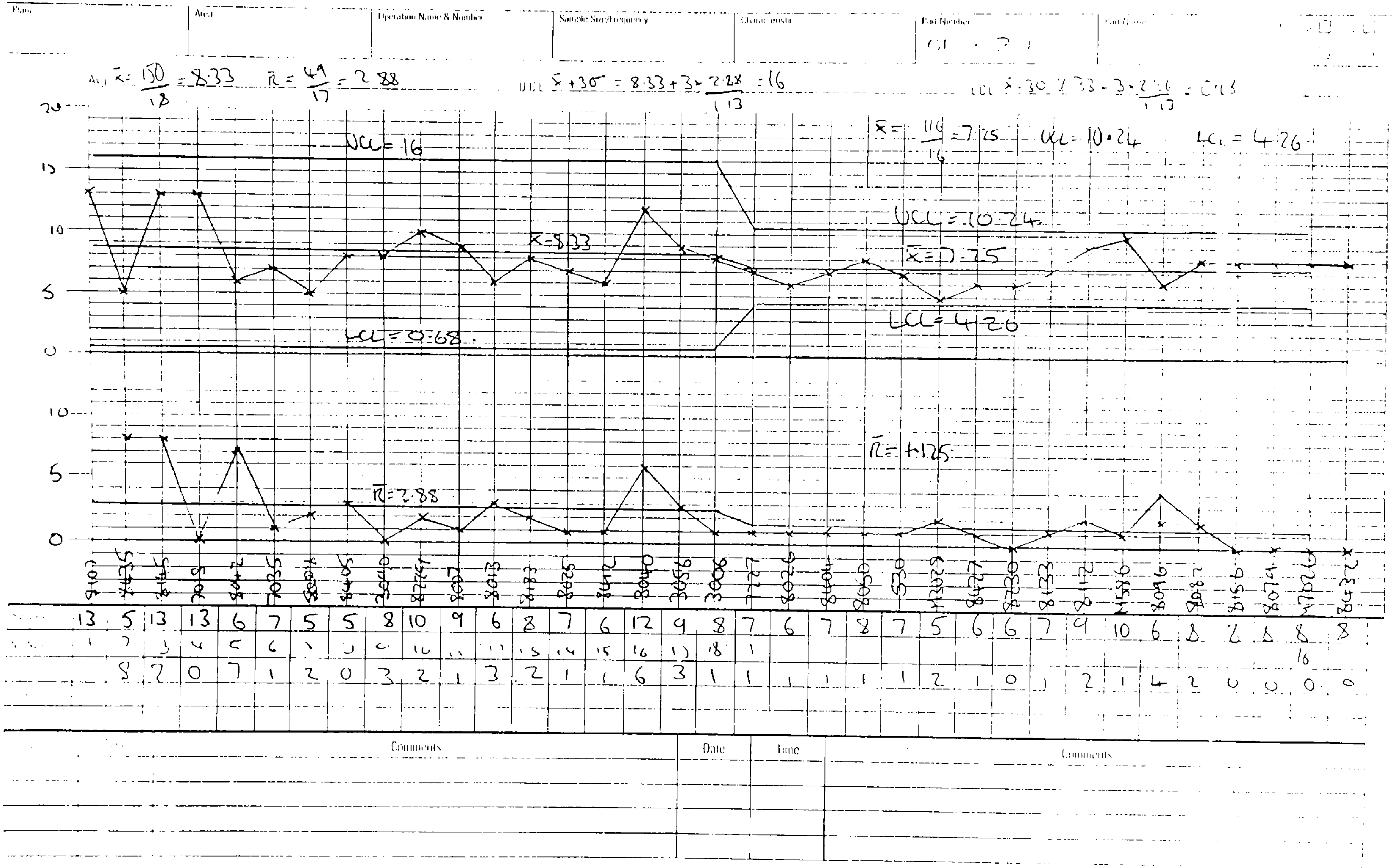


11	6	6	8	8	7	10	12	10	8	6	4	9	5	8	4	6	5	4	6	3	6	4	3	7	11	3	6	8	5	6	6	7	14	15
	5	0	2	0	1	3	2	2	2	2	2	5	4	3	4	2	1	1	2	3	3	2	1	4	4	3	3	2	3	1	0	1	7	1

Comments | Date | Time | Comments

Control Chart
Attribute Data

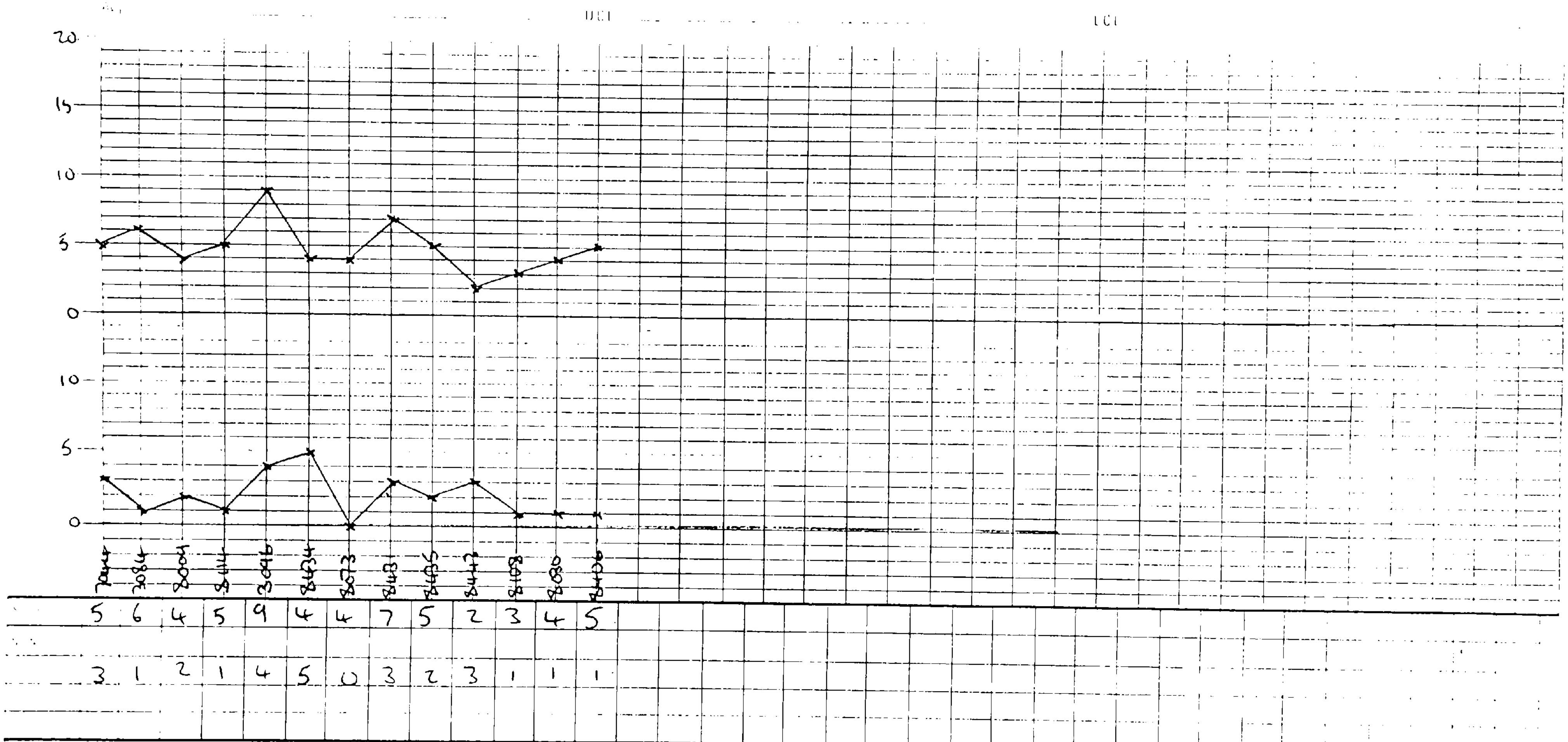
RB211 01 Module (3) TAT Time SPC Chart



Control Chart
Attribute Data

RB211 01 Module (4) TAT Time SPC Chart

01 - (4)



Comments	Date	Time	Comments

Control Chart
Attribute Data

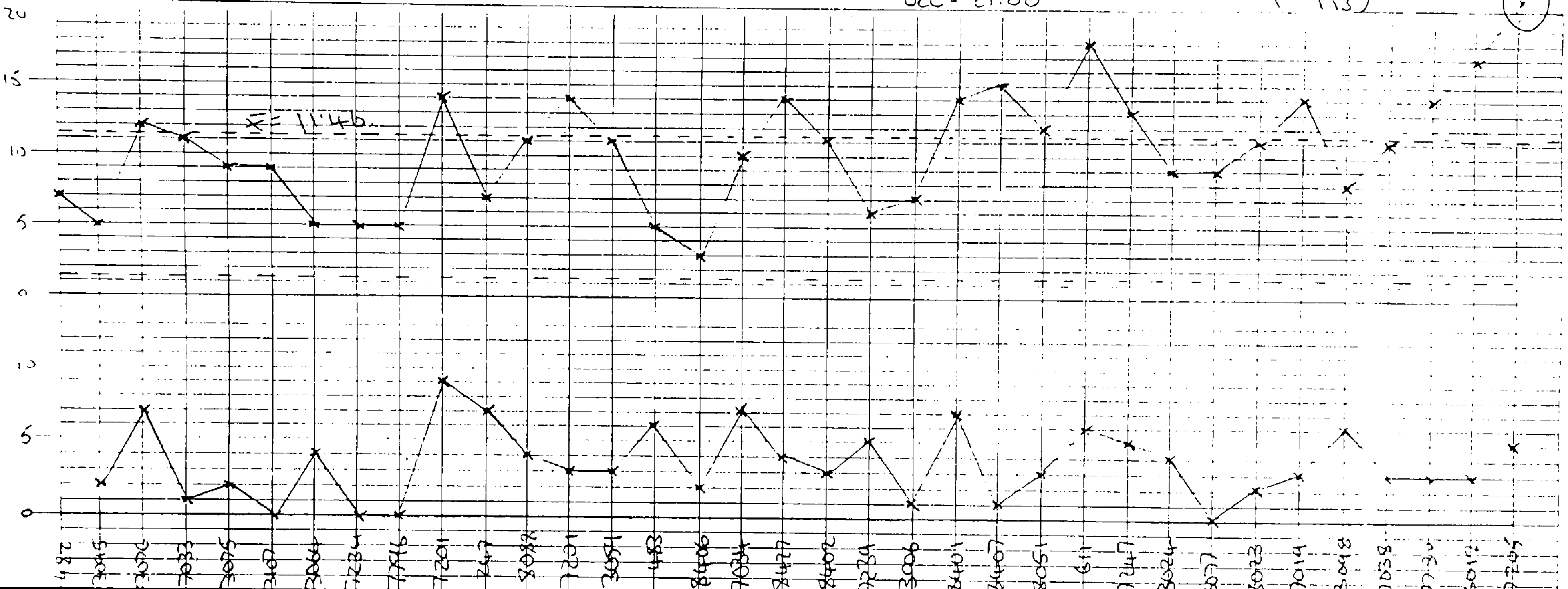
RB211 02 Module (1) TAT Time SPC Chart

02 - 1

$\bar{\bar{x}} = \frac{401}{35} = 11.46$, $\bar{R} = \frac{123}{34} = 3.62$

UCL $\bar{x} + 3\sigma = 11.46 + \left(3 \times \frac{3.62}{1.13}\right) = 21.07$ UCL = 21.00

LCL $\bar{x} - 3\sigma = 11.46 - \left(3 \times \frac{3.62}{1.13}\right) = 1.35$

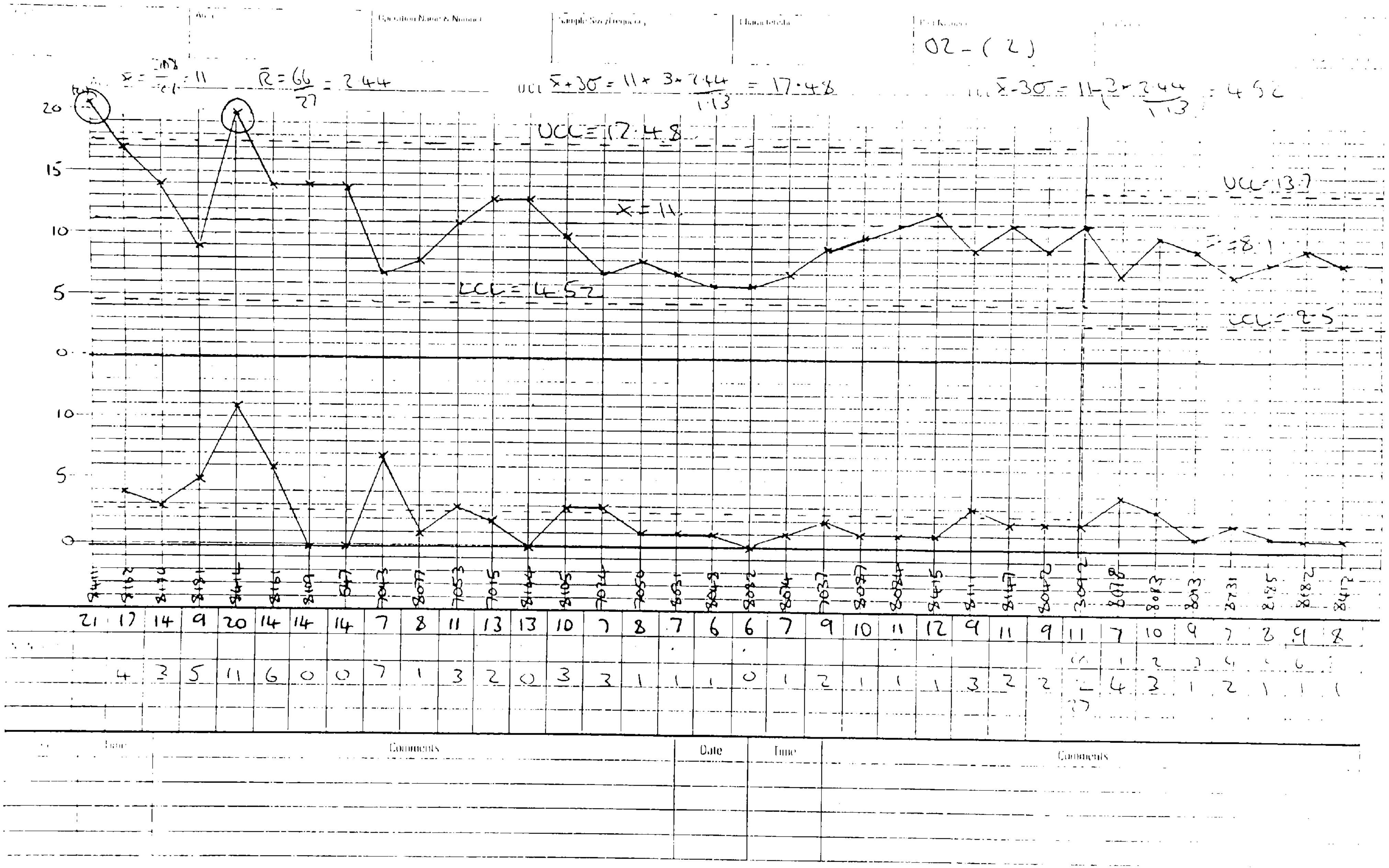


7	5	12	11	9	9	5	5	5	14	7	11	14	11	5	3	10	14	11	6	7	14	15	12	18	13	9	9	11	14	8	11	14	17	22 / 35
	2	7	1	2	0	4	0	0	9	7	4	3	3	6	2	7	4	3	5	1	7	1	3	6	5	4	0	2	5	6	3	3	3	5 / 34

Comments	Date	Time	Comments

Control Chart
Attribute Data

RB211 02 Module (2) TAT Time SPC Chart



Control Chart
Attribute Data

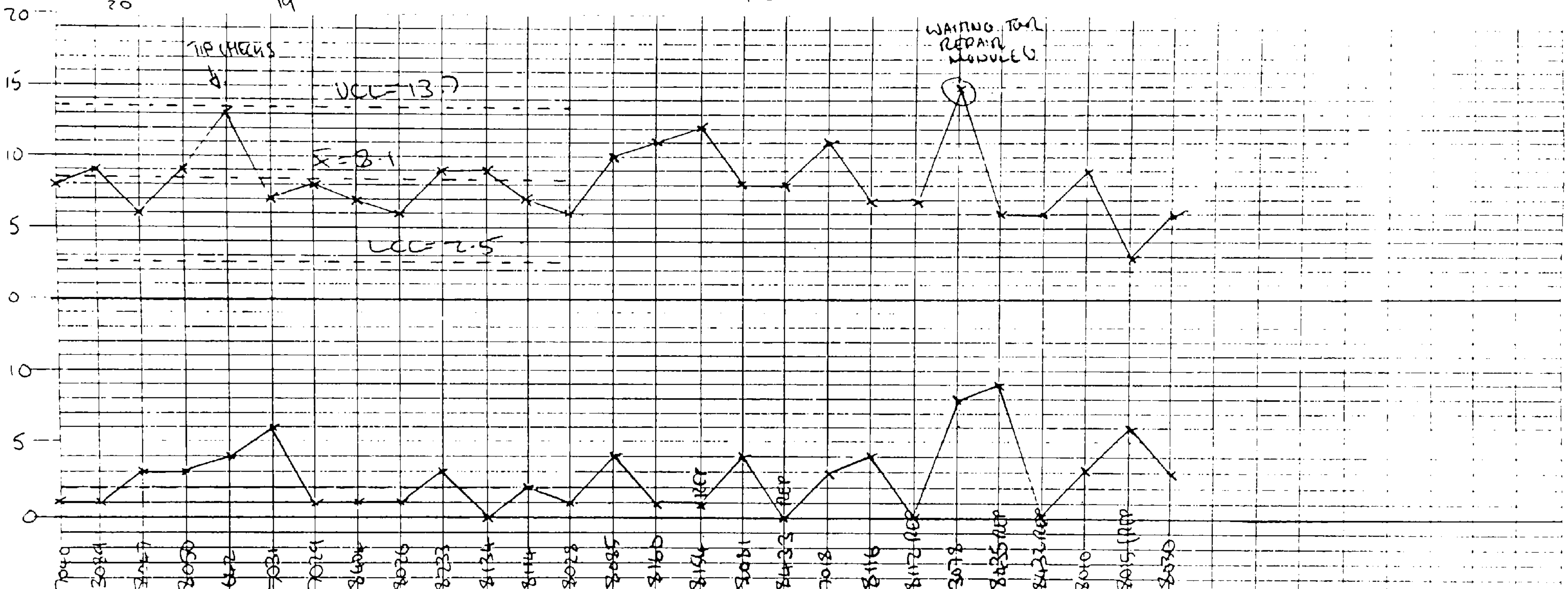
RB211 02 Module (3) TAT Time SPC Chart

Part Number: 02 - (3)

$\bar{\bar{X}}_{AVE} = \frac{162}{20} = 8.1 \quad \bar{R} = \frac{40}{19} = 2.11$

UCL $\bar{x} + 3\sigma = 8.1 + 3 \times \frac{2.11}{1.13} = 13.7$

LCL $\bar{x} - 3\sigma = 8.1 - 3 \times \frac{2.11}{1.13} = 2.5$



8040	3084	8474	8090	8472	8031	8024	8484	8026	8233	8134	8114	8028	8085	8166	8154 REP	8081	8433 REP	3018	8116	8112 REP	3078	8435 REP	8432 REP	8040	8015 (REP)	8030
8	9	6	9	13	7	8	7	6	9	9	7	6	10	11	12	8	8	11	7	7	15	6	6	9	3	6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12	3	4	5	6	7	[illegible]	[illegible]	10	[illegible]	12	[illegible]	14
1	1	3	3	4	6	1	1	1	3	0	2	1	4	1	1	4	0	3	4	0	1	9	0	3	6	3

Comments	Date	Time	Comments

Control Chart
Attribute Data

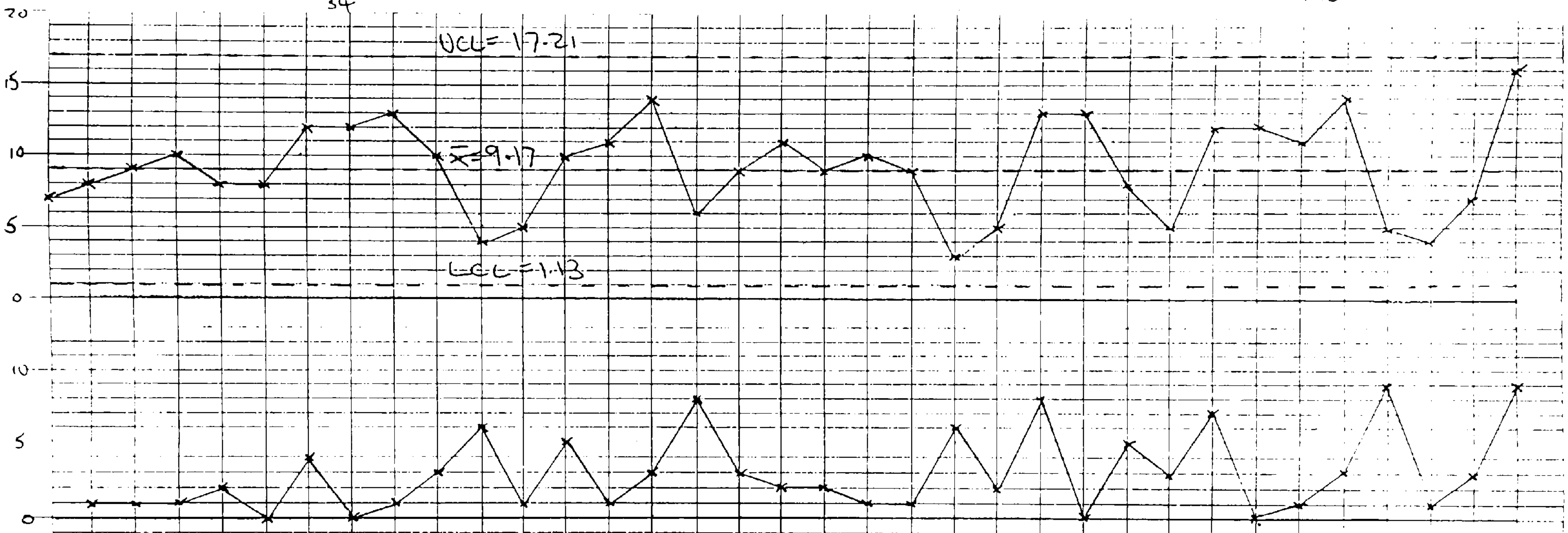
RB211 03 Module (1) TAT Time SPC Chart

03 - (1)

$\bar{x} = \frac{321}{35} = 9.17$, $\bar{R} = \frac{103}{34} = 3.03$

UCL $\bar{x} + 3\sigma = 9.17 + 3 \times \frac{3.03}{1.13} = 17.21$

LCL $\bar{x} - 3\sigma = 9.17 - 3 \times \frac{3.03}{1.13} = 1.26$



Serial	5172	3076	3078	3084	3063	7001	449	8086	7207	8401	8126	7085	8427	8402	8407	7024	3047	7246	3044	3082	8023	7076	8414	7034	8160	8174	3093	8107	7041	7766	8083	8144	8031	8103	7245
Value	7	8	9	10	7	7	12	12	13	10	4	5	10	11	14	6	9	11	9	10	9	3	5	13	13	8	5	12	12	11	14	5	4	7	16
Range		1	1	1	3	0	5	0	1	3	6	1	5	1	3	8	1	2	2	1	1	6	2	8	0	5	3	7	0	1	3	9	1	3	9

Date	Time	Comments	Date	Time	Comments

Control Chart
Attribute Data

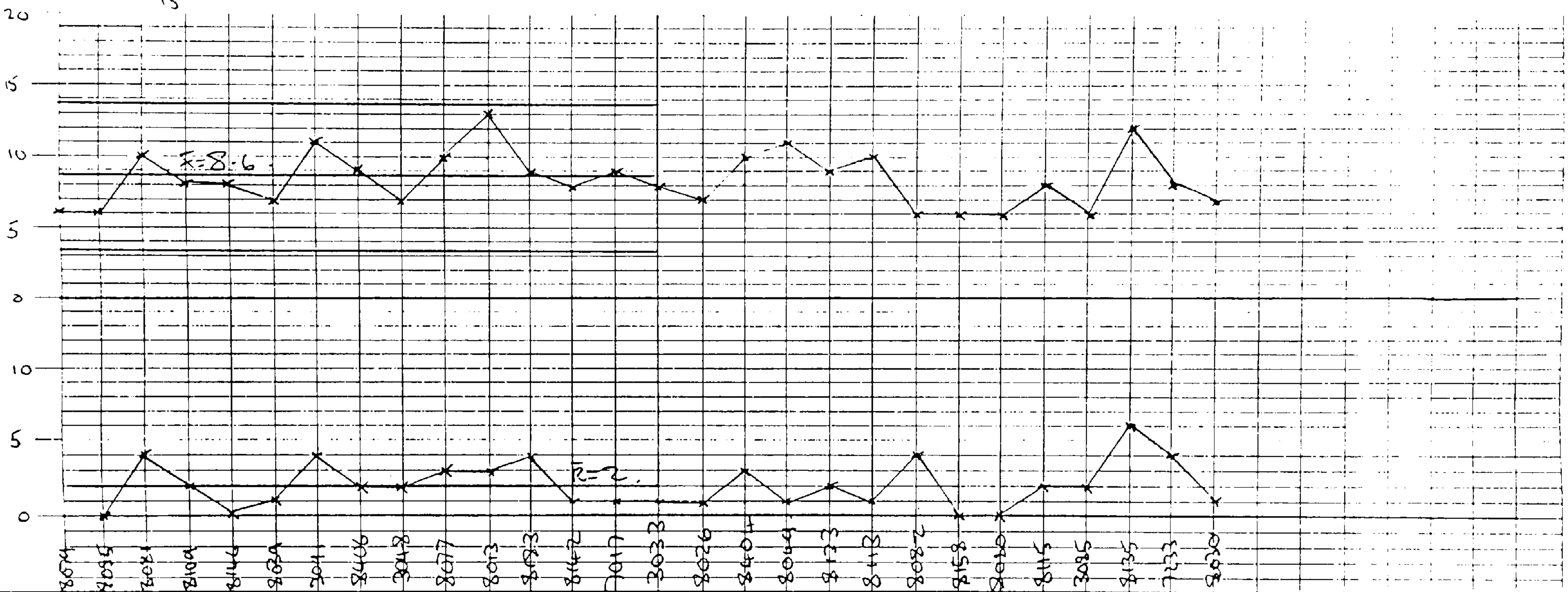
RB211 03 Module (2) TAT Time SPC Chart

Part Number: 03 - (2)

Avg $\bar{x} = \frac{129}{15} = 8.6$ $\quad \bar{R} = \frac{28}{14} = 2$

UCL $UCL = \bar{x} + 3\sigma \quad 8.6 + 3 \times \frac{2}{1.13} = 13.9$

LCL $LCL = \bar{x} - 3\sigma = 8.6 - 3 \times \frac{2}{1.13} = 3.29$



8074	8095	8081	8109	8146	8034	3041	8406	3048	8077	8013	8083	8142	3017	3033	8026	8404	8049	8133	8113	8082	8158	8010	8115	3085	8135	7233	8030		
6	6	10	8	8	7	11	9	7	10	13	9	8	9	8	7	10	11	9	10	6	6	6	8	6	12	8	7		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	0	4	2	0	1	4	2	2	3	3	4	1	1	1	1	3	1	2	1	4	0	0	2	2	6	4	1		

Comments	Date	Time	Comments

Control Chart
Attribute Data

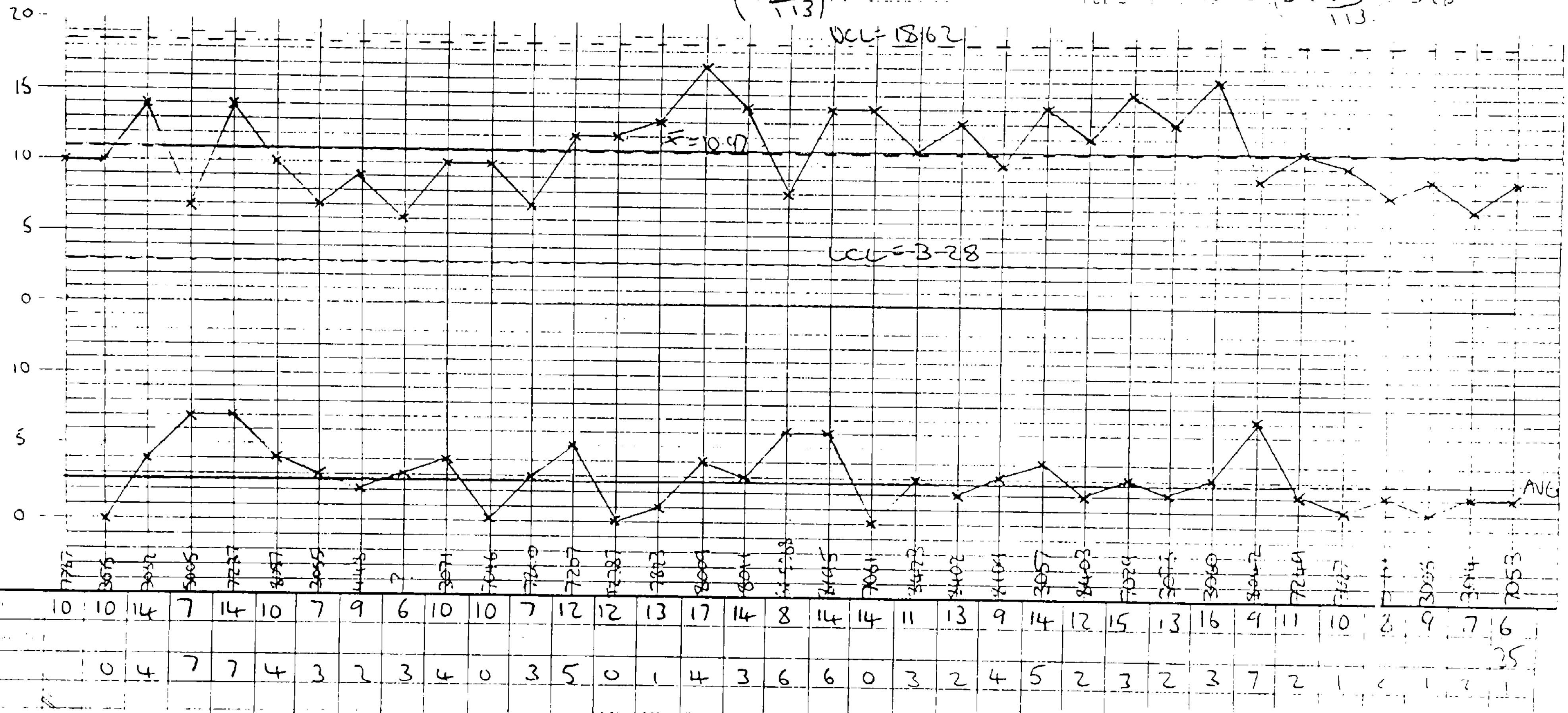
RB211 04 Module (1) TAT Time SPC Chart

Part Number: 04 MODULE 1

Avg $\bar{x}$ 10.97 RANGE AVG = 2.98

UCL $\bar{x}+3\sigma = 10.97+\left(3\times\frac{2.98}{1.13}\right) = 18.62$

LCL $\bar{x}-3\sigma = 10.93-3\times\frac{2.98}{1.13}$ 3.28



Comments

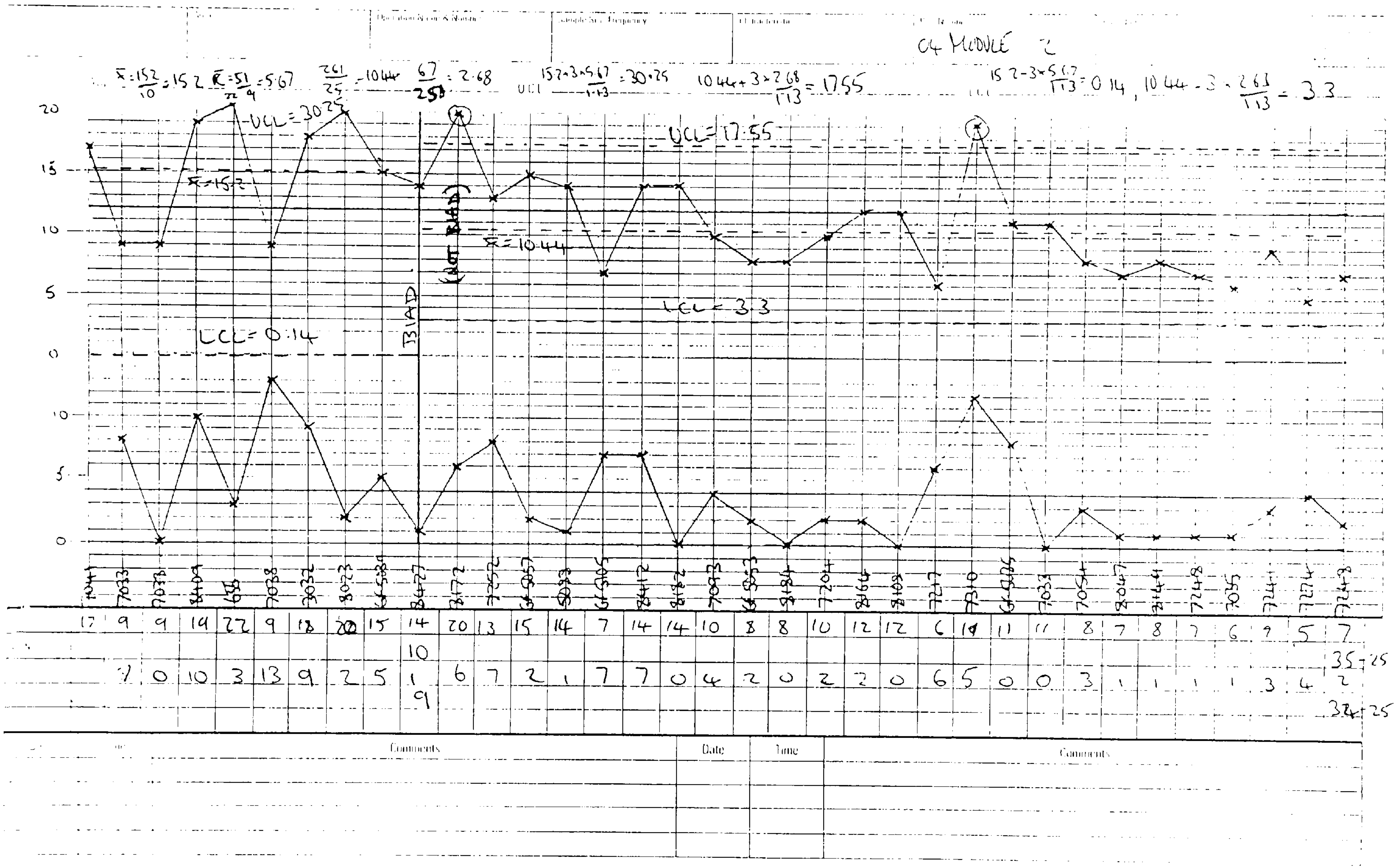
Date

Time

Comments

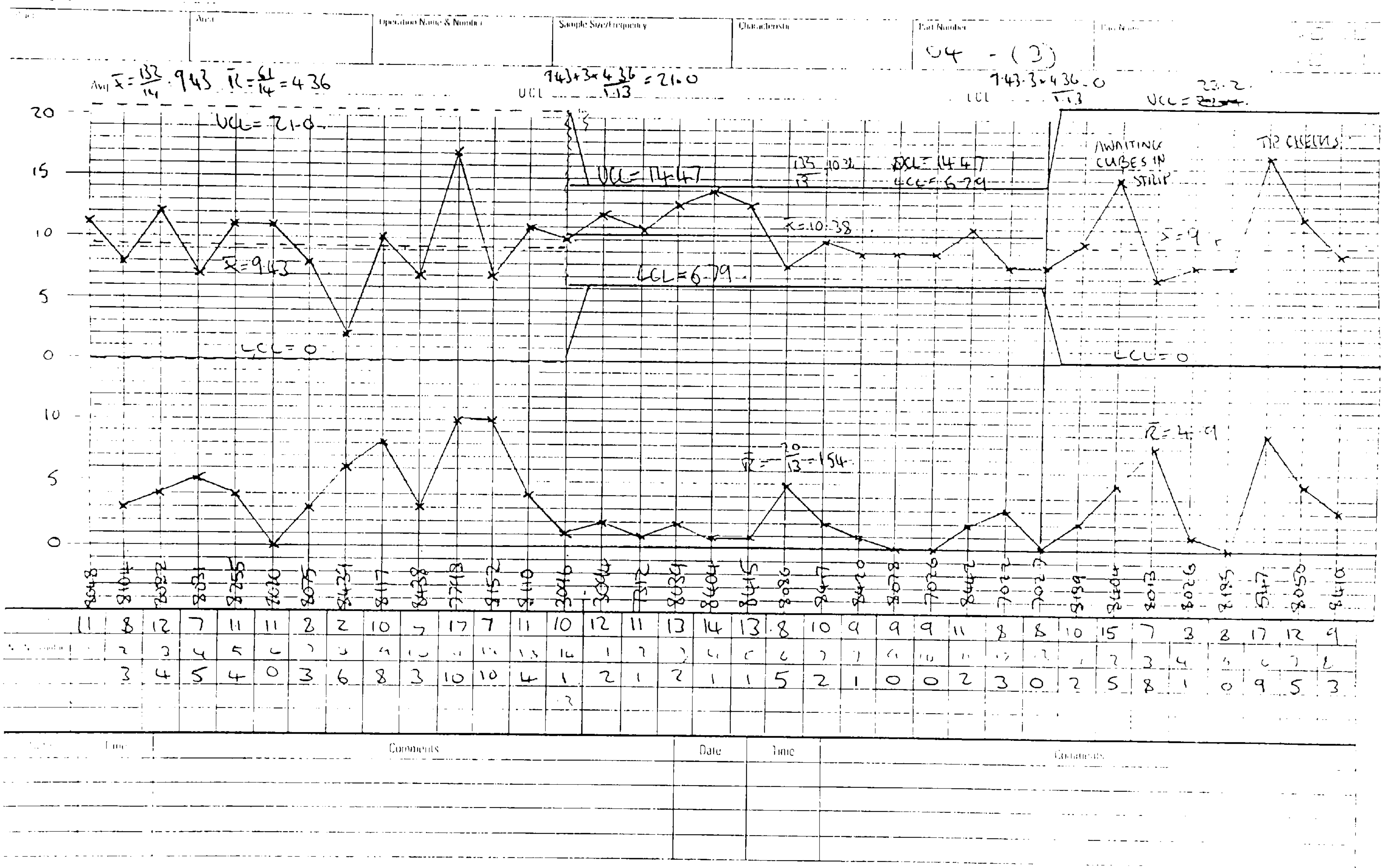
Control Chart
Attribute Data

RB211 04 Module (2) TAT Time SPC Chart



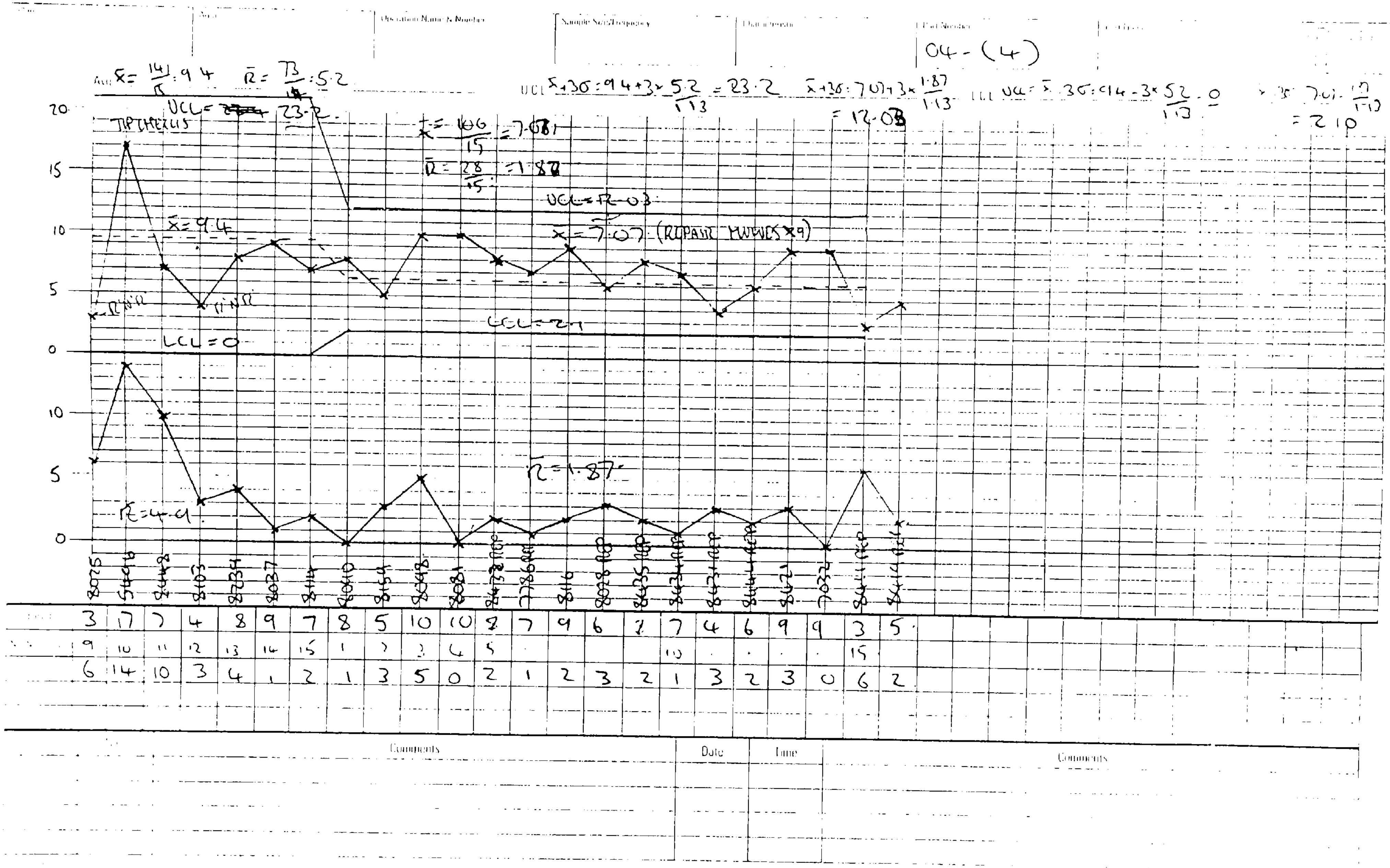
Control Chart
Attribute Data

RB211 04 Module (3) TAT Time SPC Chart



Control Chart
Attribute Data

RB211 04 Module (4) TAT Time SPC Chart



Control Chart
Attribute Data

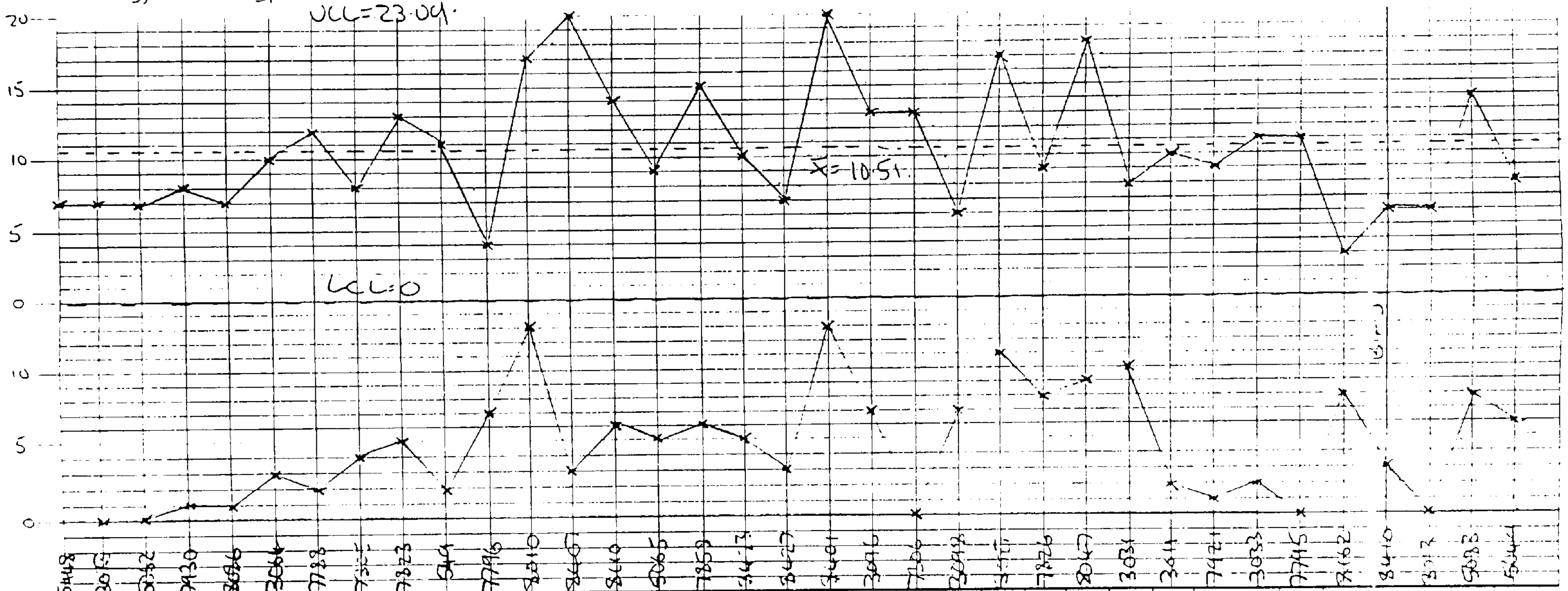
RB211 05 Module (1) TAT Time SPC Chart

Part Number: 05 - 11

$\bar{x} = \frac{368}{35} = 10.51$ $\bar{R} = \frac{161}{34} = 4.74$

UCL $\bar{x} + 3\sigma$ $10.51 + 3 \times \frac{4.74}{1.13} = 23.09$

LCL $\bar{x} - 3\sigma$ $= 10.51 - 3 \times \frac{4.74}{1.13} = 0$

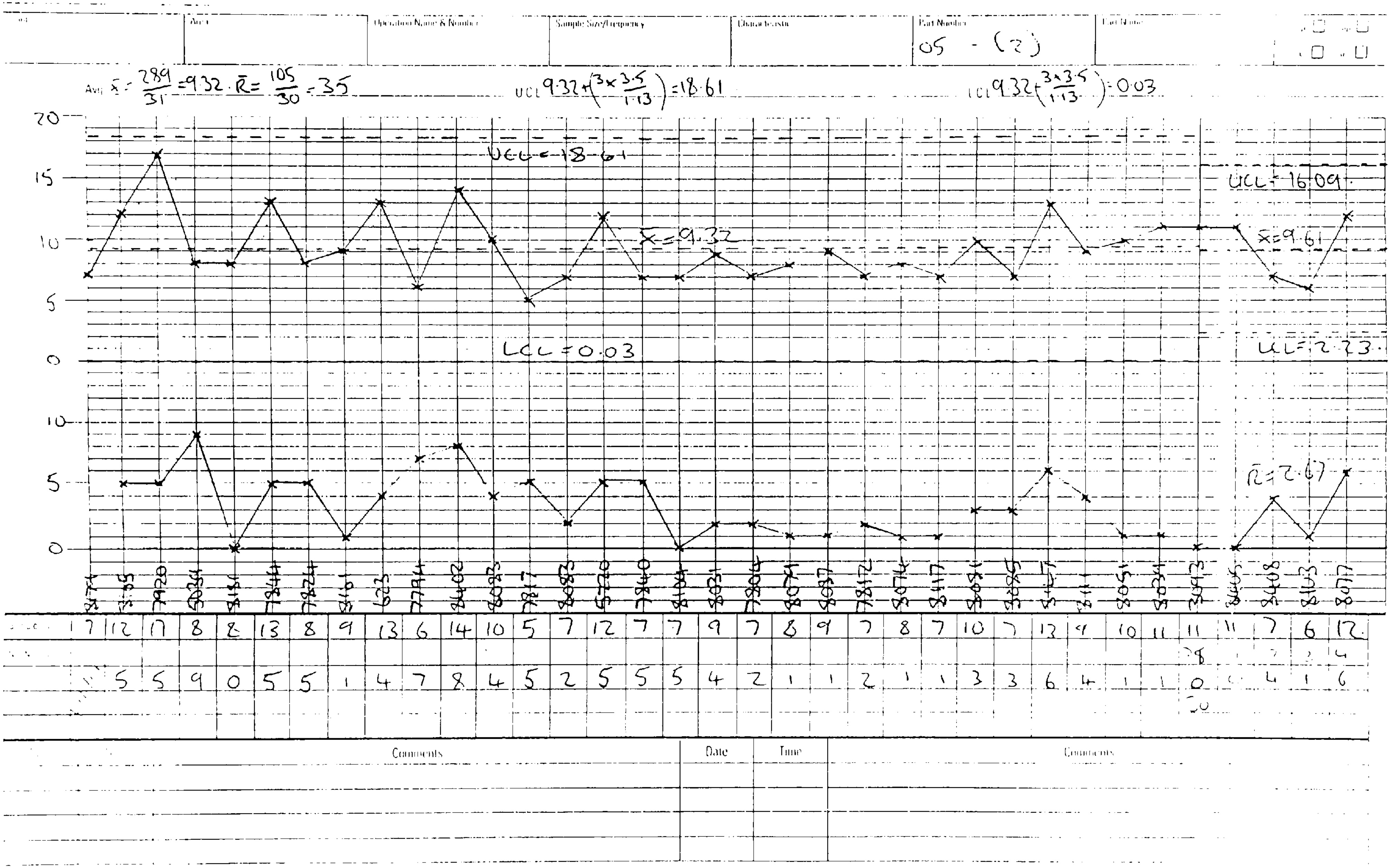


Sample value	Range
7	
7	0
7	0
8	1
7	1
10	3
12	2
8	4
13	5
11	2
4	7
17	13
20	3
14	6
9	5
15	6
10	5
7	3
20	13
13	7
13	0
6	7
17	11
9	8
18	9
8	10
10	2
9	1
11	2
11	0
[illegible]	8
6	3
6	0
14	8
8	6
35	34

Date	Time	Comments	Date	Time	Comments

Control Chart
Attribute Data

RB211 05 Module (2) TAT Time SPC Chart

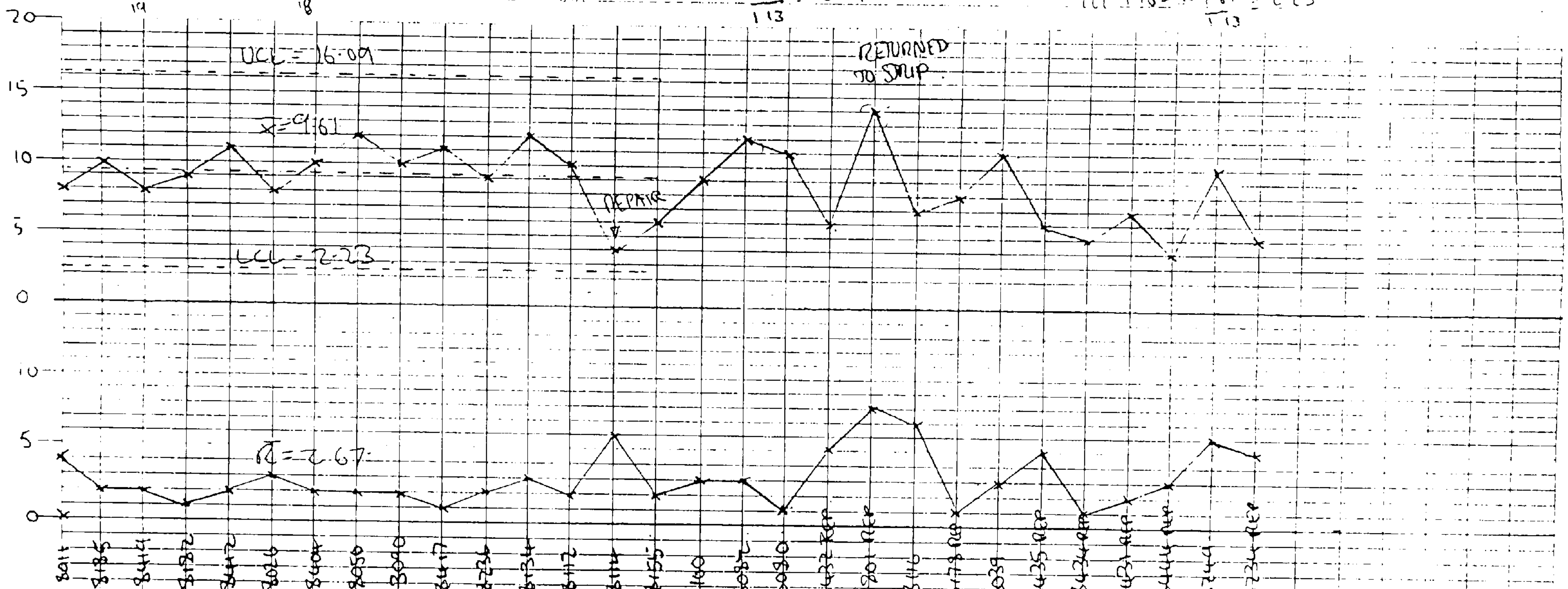


Control Chart
Attribute Data

RB211 05 Module (3) TAT Time SPC Chart

Area	Operation Name & Number	Sample Size/Frequency	Characteristic	Part Number
				05 - (3)

Avg $\bar{x} = \frac{174}{19} = 9.16$ $\bar{R} = \frac{47}{18} = 2.61$ UCL $\bar{x} + 3\sigma = 9.16 + 3 \cdot \frac{2.61}{1.13} = 16.04$ LCL $9.16 - 3 \cdot \frac{2.61}{1.13} = 2.23$



	8011	8185	8444	8182	8442	8046	8404	8050	8040	8417	8236	8134	8112	8114	8155	7140	8082	8080	8432 REP	7801 REP	8116	8178 REP	2039	8435 REP	8434 REP	8431 REP	8444 REP	8244	8234 REP
	2	10	7	9	11	8	10	12	10	11	9	12	10	4	6	9	12	11	6	14	7	8	11	6	5	7	4	10	5
	5	6	7	2	9	10	11	12	13	14	15	16	17	18	19	1	2	3		5					10				
	4	2	2	1	2	3	2	2	2	1	2	3	2	6	2	3	3	1	5	8	7	1	3	5	1	2	3	6	5

Comments	Date	Time	Comments